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7. Abstract

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Three geophysical surveys were conducted at the Horn Rapids Landfill measuring electromagnetic conductivity and collecting magnetometer and ground penetrating radar data. Limited test pit excavations were recommended to characterize geophysical anomalies.

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1.0 INTRODUCTION

This report presents the background, results, and interpretations of surface geophysical surveys conducted at the Horn Rapids Landfill during May 1991. This report is part of work described in the Remedial Investigation Phase II Supplemental Work Plan of the 1100 EM-1 Operable Unit (DOE-RL 1990).

The geophysical investigation at the Horn Rapids Landfill has proceeded in phases, including preliminary data analysis and forward modeling, followed by field surveys of the site. The objectives of the field survey were to:

- Further delineate the trench boundaries and identify areas potentially containing 10 or more buried drums of volatile organic compounds (VOC), specifically carbon tetrachloride
- Identify possible locations for excavation and examination of the landfill materials to determine whether drums containing VOC are present in the landfill.

Three surveys were specified in the scope of work for the project, including surface electromagnetic induction (EMI), magnetometer/gradiometer (MAG), and ground-penetrating radar (GPR). EMI and MAG surveys were recommended to fully delineate trenched areas and identify local conductivity or magnetic anomalies which might indicate deposits of metallic objects, possibly buried drums. The purpose of the GPR survey was to provide detailed information on the depth and lateral extent of buried features that might be associated with the EMI and MAG anomalies.

2.0 BACKGROUND

The following sections provide background information on the Horn Rapids Landfill. Figure 1 shows the location of the Horn Rapids Landfill and surrounding facilities.

2.1 PREVIOUS ENVIRONMENTAL INVESTIGATIONS

A number of environmental investigations have been undertaken at the Horn Rapids Landfill pursuant to both the initial and second phases of the 1100-EM-1 Operable Unit remedial investigation (RI). A scoping and source investigation review of existing information, including interviews with former Hanford Site employees familiar with the landfill, indicated that the Horn Rapids Landfill is a solid waste facility that was used primarily for the disposal of office and construction debris and the burning of classified documents. Asbestos, sewage sludge, fly ash, and, potentially, drums of unidentified organic liquids, are alleged to have been disposed at this facility. Surface geophysics techniques were used to delineate areas of waste deposition within the landfill. These geophysical surveys indicated four trench areas containing buried waste materials. The results of these surveys are discussed in Section 2.2. Figure 2 shows the extent of the trench areas identified in the initial surveys.

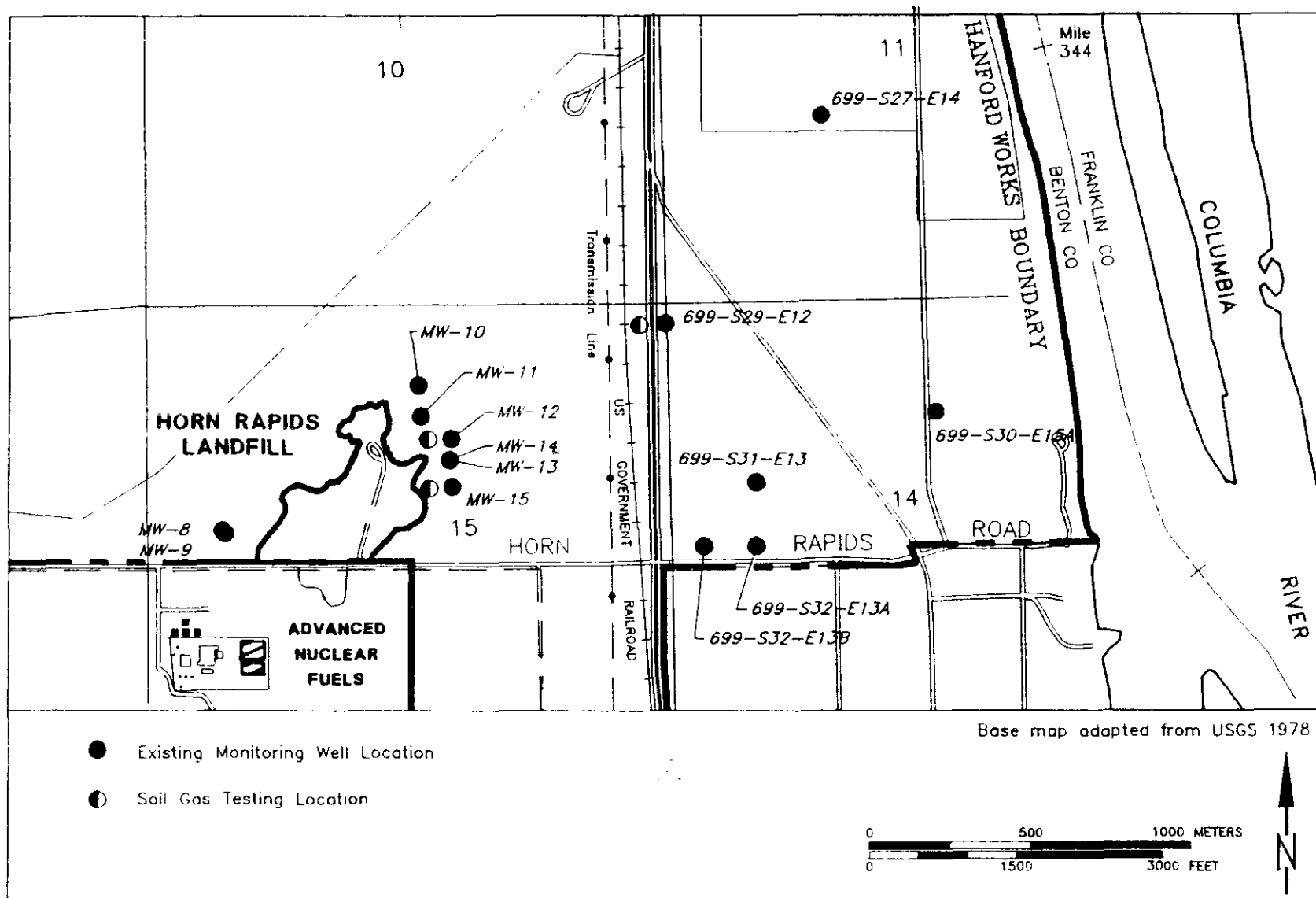
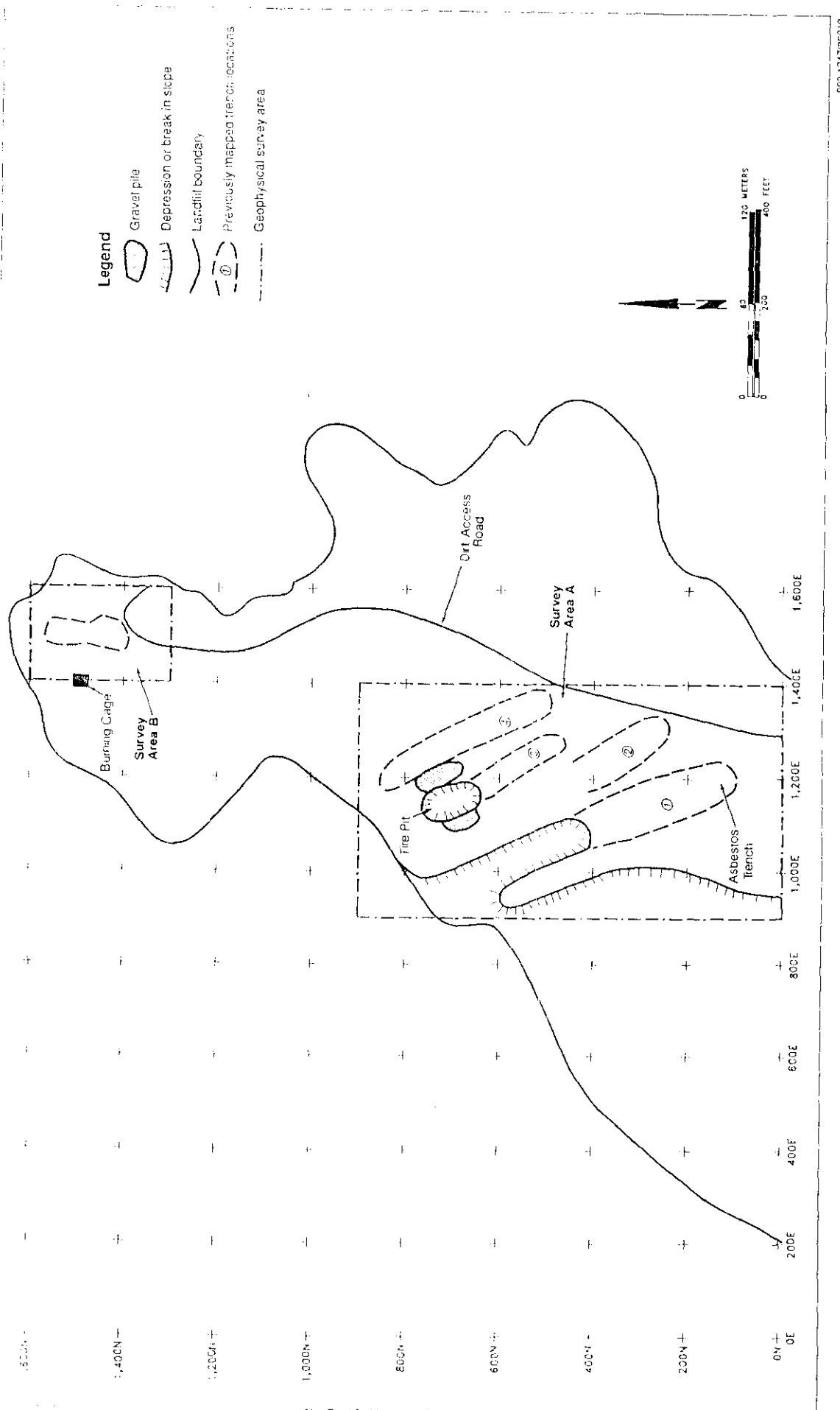


Figure 1. Location Map of Horn Rapids Landfill.



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Figure 2. Survey Location Map and Major Features.

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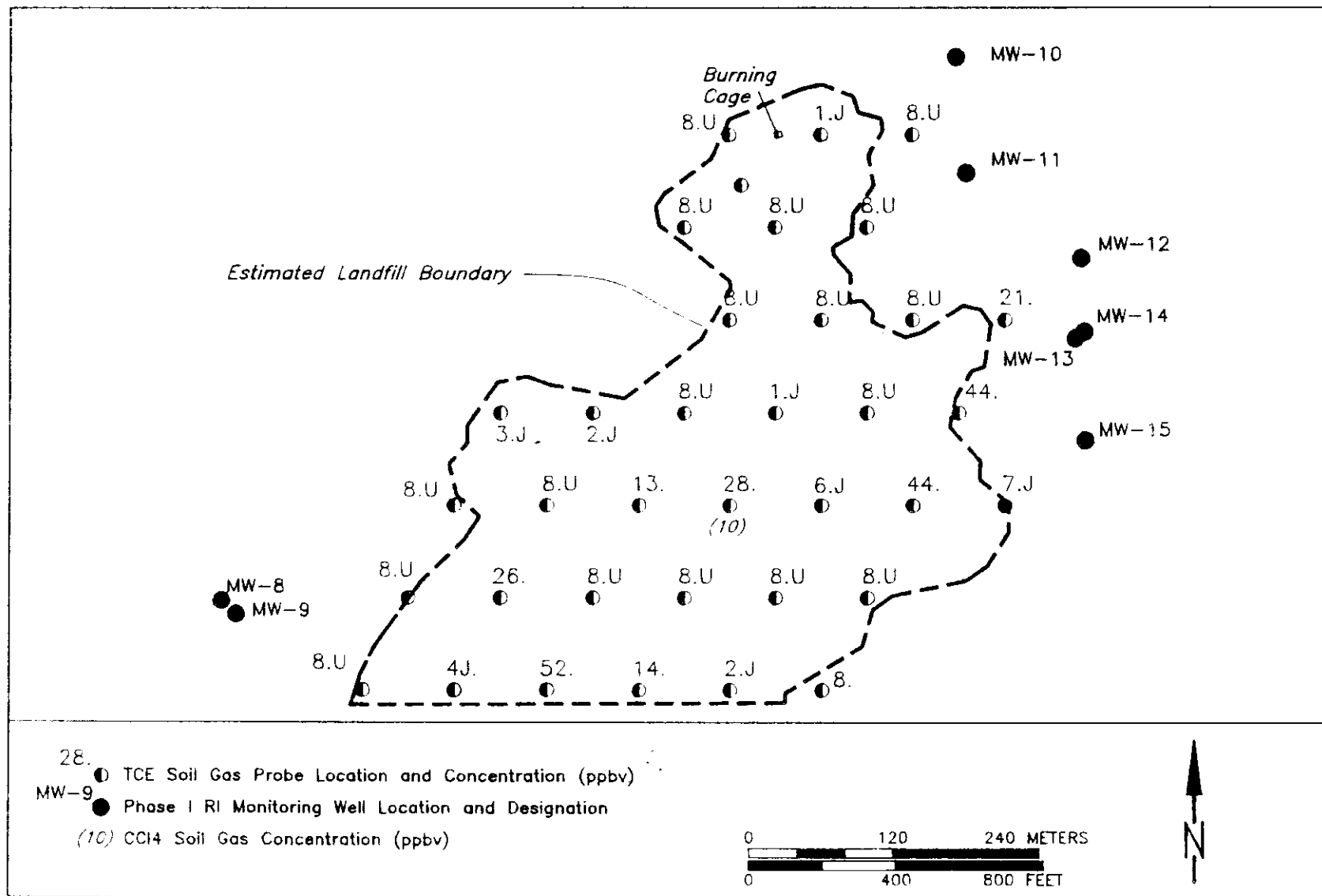
A meteorological investigation showed that the Horn Rapids Landfill is located in an area with a moderately semiarid climate that is characterized by low precipitation, high evapotranspiration, and light winds. Ambient air monitoring and emissions modeling indicated that the Horn Rapids Landfill does not adversely impact air quality from the perspective of any onsite workers, offsite workers, or nearby residents. A human and wildlife ecological investigation was also conducted. Land use of the Horn Rapids Landfill and the surrounding vicinity is industrial, and groundwater is not used in the area downgradient of the landfill. No cultural resources, of either an archeological or historical significance, are located within the landfill vicinity. The landfill is located within a shrub-steppe vegetational zone characterized by the presence of a sagebrush/bunchgrass plant community in undisturbed areas and a cheatgrass/rabbitbrush/tumbleweed community in areas, such as the Horn Rapids Landfill, disturbed by human activities.

No surface water bodies are located within the landfill vicinity; however, the Columbia River, an important regional surface water resource, is located approximately 1.5 mi to the east of the Horn Rapids Landfill. The water quality of the unconfined aquifer, which flows from southwest to northeast beneath the landfill, was investigated during the Phase I RI. Although former employees alleged that some waste within the landfill was deposited below the water table, the initial hydrogeological investigation gave no indication of groundwater contamination attributable to the Horn Rapids Landfill.

Groundwater contamination, characterized predominantly by the presence of trichloroethene, nitrate, and radiation is present immediately downgradient of the landfill. However, the concentrations of these contaminants are not discernibly different from those found immediately upgradient. All data collected to date suggest that the pretreatment ponds at the Advanced Nuclear Fuels Corp. (ANF), a commercial nuclear fuel fabrication complex (Figure 1), are the primary source of this contamination (DOE-RL 1990). ANF's ponds are known to have leaked during the 1970's, causing documented groundwater contamination (Lickhaven 1990). Additional groundwater investigation activities are being performed during the second phase of the RI.

During the initial stages of the Phase II RI, Golder Associates, Inc., (Golder) conducted a soil-gas survey in the Horn Rapids Landfill vicinity, including the South Pit and the northern portions of the ANF complex (Golder 1991a). No indications of a volatile organic source of contamination were found within the landfill, including the South Pit. Downgradient from the ANF pretreatment ponds, including across the landfill, more or less uniform, low-level concentrations of trichloroethene were encountered, as shown in Figure 3.

Figure 3. Location of Soil-Gas Probes and Monitoring Wells at Horn Rapids Landfill.



2.2 SITE DESCRIPTION

The site topography is generally flat, and is covered by shrubs and grasses. Subsidied areas exist on the site, which correspond with known trench or fill areas. It appears that the landfill is constructed of natural fill materials, which have subsequently been trenched. The eastern edge of the landfill corresponds to a distinct break in slope with about 20 ft of vertical relief. The base of this slope appears to be the original ground surface. The natural ground surface rises gradually to the north and intersects the grade of the landfill near the northern entrance to the asbestos trench. The northern portion of the asbestos trench is open, with a maximum of 15 ft of elevation difference between the base of the trench and the top of the landfill. These slopes are composed of coarse gravel and cobbles. Additionally, a large open pit containing tires exists at the northeastern edge of the landfill. This pit is bordered by two large piles of gravel. Figure 2 shows the geophysical survey areas and major topographic and surface features of the landfill.

Metallic debris is found on the ground surface throughout the site, including partially exposed pipes, sheet metal, rebar, angle-iron, wire, and cable. In the northern edge of the asbestos trench, abundant metallic debris can be seen protruding from the slope break of the trench. A large metallic structure (burning cage) exists at the northern end of the site.

2.3 PREVIOUS RECONNAISSANCE GEOPHYSICAL SURVEYS

Reconnaissance geophysical surveys were carried out by Pacific Northwest Laboratory (PNL) in 1989 using EMI, magnetometer, and GPR techniques on a 100-ft line spacing (PNL 1989). Data were presented as a series of profiles corresponding to each trackline. Additionally, maps showing areas of anomalous response were prepared. Anomaly magnitudes or lateral distribution were not presented on these plan view maps. The survey delineated four northwest/southeast trending anomalies, corresponding to burial trenches (PNL 1989) known to exist at the Horn Rapids Landfill. Electromagnetic anomalies showed relative amplitudes of over 2,000 gammas, indicating highly conductive material within the trenched areas. Magnetometer anomalies of up to 4,000 gammas were observed over the trenches, suggesting that iron or steel objects exist in the trenches. The GPR data was of limited use in characterizing the conductive EMI and MAG anomalies. The raw data was acquired and stored in an obsolete tape format that was incompatible with most computers. A set of 3-in. by 5-in. photographic transparencies of the processed data were provided, but were difficult to examine because of their size. Therefore, the reconnaissance nature of the survey (100-ft line spacing) and the data display format prevented detailed evaluation of trench anomalies.

2.4 FORWARD MODELING

Golder performed preliminary forward modeling of potential magnetometer responses at the Horn Rapids Landfill. A magnetics model, GMSYS, developed by Northwest Geophysical Associates, Inc., was used to produce theoretical magnetometer profiles over various configurations of drums within a trench. This model incorporates a number of variables including remnant magnetization

(field strength, inclination, and declination), survey azimuth, and performs 2 1/2-dimensional calculations, such that strike length of the magnetic targets can be incorporated. This is particularly useful for modeling drums, which have a finite strike length. A complete discussion of model parameters is provided in the interim deliverable on forward modeling prepared during April 1991 (Golder 1991b).

The objectives of the preliminary modeling were the following:

- Evaluate the theoretical response corresponding to a collection of 10 buried drums and develop a set of simple baseline magnetic models that could possibly be used to discriminate "10-drum" anomalies from responses caused by smaller objects. These responses could then be used during data processing, and also in the field to focus GPR surveys in areas most likely to contain drums
- Develop a methodology for conducting, processing, and interpreting the geophysical data acquired in the field.

The results of the modeling indicated that a collection of drums within a trench free of other magnetic materials would have a magnetometer anomaly wavelength between 40 and 80 ft with an amplitude between 100 and 2,000 gammas, depending on the depth of burial. For the purposes of the field survey, a threshold amplitude of 300 gammas was chosen. Limited simulation of high background susceptibilities indicated that background trench susceptibility could significantly mask the response of smaller targets within the trench. However, theoretical models describing magnetometer responses in areas with high background susceptibility do not exist.

3.0 TECHNICAL BACKGROUND

3.1 ELECTROMAGNETIC INDUCTION

The EMIs are common in shallow environmental geophysical investigations and are used to determine the electrical conductivity of the subsurface. An electromagnetic current is introduced into the subsurface via a transmitting coil, and the resultant secondary electromagnetic field is measured at a receiving coil. The penetration depth of the technique is dependent on the electrical conductivity of the subsurface and the distance between the transmitter and receiver. For the shallow investigation of the Horn Rapids Landfill, a Geonics EM-31 (a tradename of Geonics, LTD) instrument was used. The EM-31 has a coil separation distance of 3 m, for an approximate penetration depth of 18 ft. Two measurements are collected: quadrature and in-phase component. The quadrature component is expressed as apparent ground conductivity in mmhos/m. The in-phase component of the measured secondary field is more sensitive to highly conductive materials such as metal, and is expressed in parts-per-thousand (ppt). Both components will produce anomalies over metallic objects, but the quadrature component also responds to other electrically conductive materials such as clay or brine.

3.2 MAGNETOMETER/GRADIOMETER

Magnetometer surveys are often used in environmental geophysical investigations to identify areas containing buried ferromagnetic metallic debris, particularly iron and steel objects such as drums. The technique measures the natural magnetic field of the earth. Ferromagnetic materials, such as iron or steel, create local disturbances in the earth's magnetic field that can be detected with the magnetometer. The strength and shape of an anomaly detected with a magnetometer is dependent on a number of features including the magnetic susceptibility of the target, target depth, and orientation of the target with respect to the earth's field.

Magnetic susceptibility is not a well defined parameter for most materials and published values usually range over orders of magnitude. Basalt typically has a susceptibility of 10^{-3} to 10^{-5} cgs. Iron and steel have high susceptibilities ranging from 1 to 10^6 . The susceptibility of iron or steel is typically between 1 and 10 cgs and often up to 100 cgs (Breiner 1973). A typical material susceptibility for drums or pipes is between 20 and 30 cgs. However, the actual effective susceptibility of a pipe or drum is less because of the effects of demagnetization effect (Grant and West, 1968) and the relative volume of metal in the target (EG&G 1988).

Theoretical values of effective susceptibility values for single drums range from 0.2 to 0.5 cgs, while values determined from modeling of field data (Gilkeson 1986; Barrows 1988) typically range from 0.1 to 0.2 cgs. From a practical standpoint, it is not necessary to determine the actual susceptibility of metallic targets, but rather to know that there is a large contrast in susceptibility between the targets and the surrounding soil. Clearly, a drum, collection of drums, or other ferromagnetic material in the Horn Rapids Landfill will have a much higher susceptibility than the surrounding gravel, even if the gravel is composed of basalt. More serious complications are evident in magnetically noisy environments, such as landfills. Barrows and Rocchio (1988) suggests that landfills containing more than 10% by volume of metallic material may exhibit a condition called saturation susceptibility. Saturation susceptibility within a landfill causes the entire landfill or particular landfill cell to mask the response of individual targets within the landfill cell.

3.3 GROUND-PENETRATING RADAR

GPR systems transmit high frequency (80 to 500 MHz) radar pulses into the subsurface and record the amplitude and arrival time of reflected pulses. An antennae mounted on a fiberglass sled is pulled along the surface to produce a profile of the radar reflections along a trackline. A tape recording system can optionally be included to record the analog signal for later digitization and processing of the records. Penetration depth of a GPR signal is dependent on the conductivity of the subsurface, and can range from <5 ft to hundreds of feet in ice. GPR surveys can be used to accurately locate shallow buried drums, pipes, and utilities. Under ideal conditions, GPR reflections exhibit a characteristic parabolic reflection pattern due to diffraction of the radar signal over cylindrical targets. Similarly, high contrasts in electrical properties can produce ringing, or multiple reflections of the signal.

4.0 FIELD SURVEY AND RESULTS

4.1 OVERVIEW

Three geophysical surveys were conducted from May 5, 1991, through May 12, 1991, at the Horn Rapids Landfill by Golder and its subcontractor Williamson and Associates Inc. Personnel from Science Applications International Corporation (SAIC) also assisted with the field survey. The geophysical surveys were conducted over two portions on the landfill identified as potentially trenched areas in previous surveys (Figure 2). Area A is located in the southern portion of the site over the four suspected trenches identified in the reconnaissance survey and covers 10.3 acres (500 by 900 ft). Area B is located in the northern portion of the site and covers 1.4 acres (200 by 300 ft). The detailed grid used in the survey is shown on Figure 4.

Discrete electromagnetic (EM) conductivity measurements were collected on 10 by 20 ft grid corner points using an EM-31 ground conductivity meter. Measurements were collected at each grid point following Technical Procedure TP-1.1-5 (Appendix D). At each station, quadrature and in-phase components of the electromagnetic field were measured in two boom orientations for a total of four measurements per station. The instrument boom was oriented both parallel and perpendicular to the survey line to provide information on heterogeneity in the subsurface material. A total of 5,712 EM conductivity measurements were collected in Area A, and 441 measurements were collected in Area B. The data were downloaded to a computer and processed in the field. These preliminary results helped in determining the optimum placement for GPR survey lines.

Discrete magnetometer data were collected on a 10 by 10 ft grid corner points. A G856 magnetometer/gradiometer (a tradename of EG&G Geometrics, Inc.) was used to collect total magnetic field data at 6 and 8 ft above ground surface. These measurements provided both total magnetic field and the total field vertical gradient data. Base station data were also collected so that diurnal variations in the total magnetic field could be removed (Figure 5). All magnetometer data were collected following Technical Procedure TP-1.7-1 (Appendix D). A total of 11,322 magnetic measurements were collected in Area A and 861 measurements were collected in Area B. These data were also downloaded directly into a computer and processed in the field to identify anomalies for optimum placement of GPR survey lines.

GPR data were collected using a GSSI SIR System 3 (a tradename of Geophysical Survey Systems, Inc., Model SIR) radar unit with a 120 MHz antennae. A Technics digital DAT tape recorder (a tradename of Technics, Inc.) was also used to record all GPR data for later playback or processing. GPR survey data were collected over 78 lines in Area A and 12 lines in Area B. Line spacing was 10 ft and line length was 80 to 400 ft. Figure 4 shows the areal coverage of the GPR surveys in Areas A and B, respectively. GPR surveys were limited to zones with large EM conductivity anomalies or total field magnetic anomalies of 300 gammas above the median base station reading as recommended in the Preliminary Analysis Report.

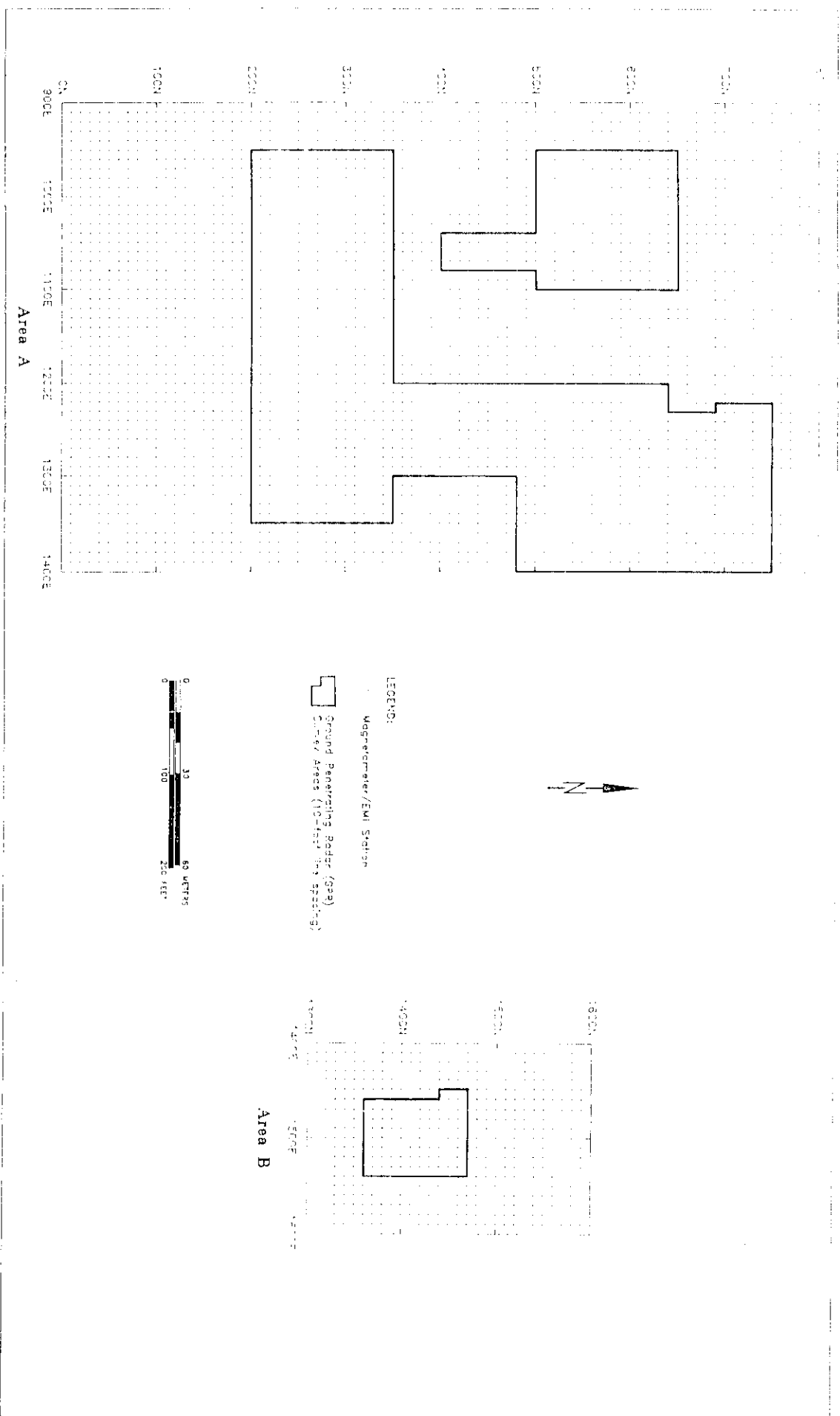


Figure 4. Geophysical Survey Areas.

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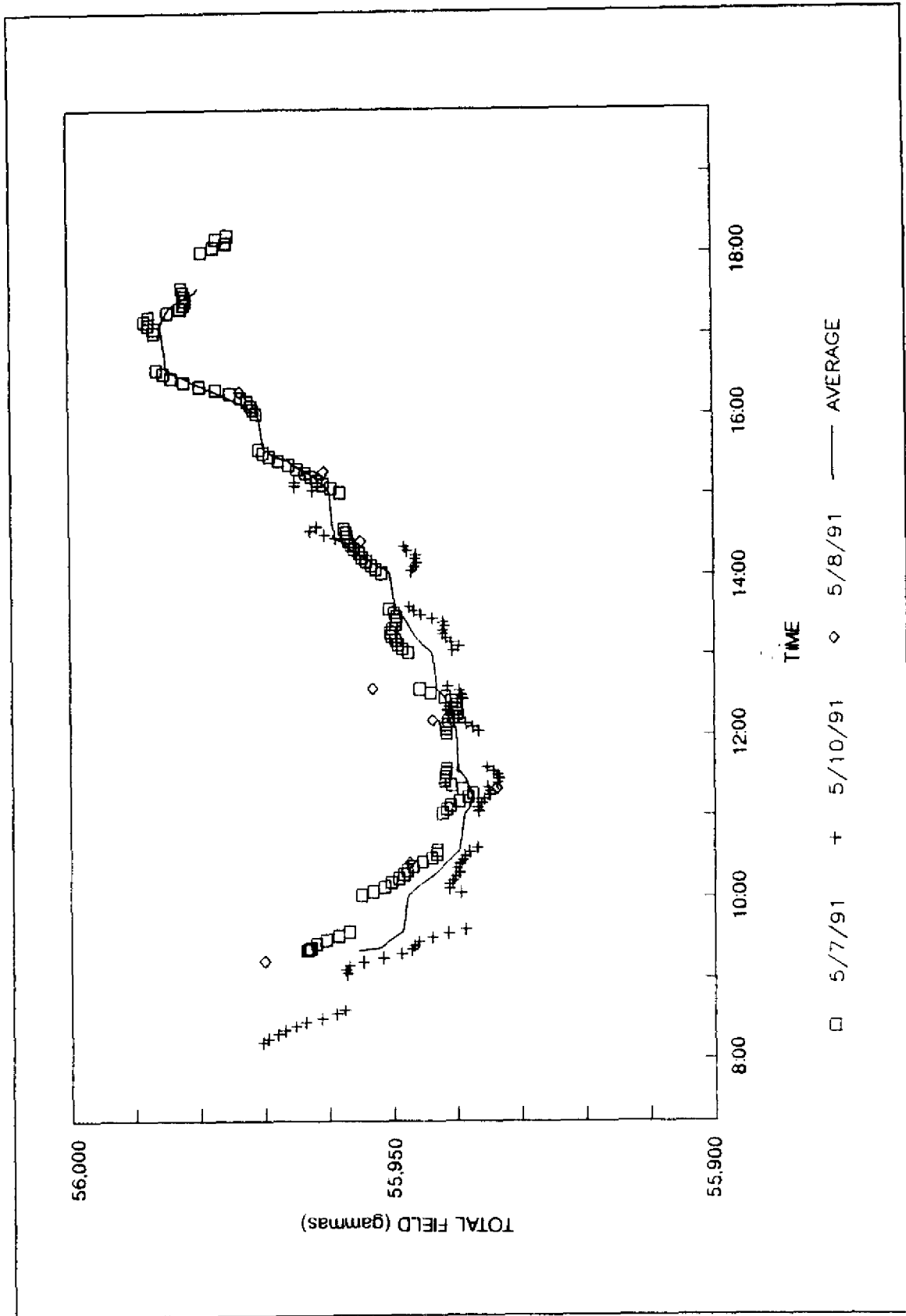


Figure 5. Base Station Fluctuations.

4.2 ELECTROMAGNETIC INDUCTION

EMI conductivity results are presented in Appendix A as contoured plots of quadrature and in-phase components in both north-south and east-west boom orientations. No in-phase component was measured at Area B due to an equipment malfunction. A total of four plots were generated for Area A and two plots (quadrature only) for Area B of the survey. Area A shows four linear patterns of high ground conductivity and in-phase response that correspond to the trench locations used for disposal at the landfill. Background conductivities of the untrenched landfill materials are between 3 and 8 mmhos/m, with an average conductivity of 4.6 mmhos/m. Conductivities within the trenches are between 8 and 45 mmhos/m, and are negative in some areas. The strongest anomalies in the trenches correspond to conductivities greater than 20 mmhos/m. The in-phase component has a similar linearity to the quadrature component, but defines individual anomalies within the trenches more distinctly. In-phase anomalies range up to 770 ppt. Average values for the in-phase component (averaged over the entire landfill) are 1.9 ppt in the north-south orientation and 0.3 ppt in the east-west orientation. Scattered in-phase anomalies were detected outside the trench areas, which appear to correspond to surface debris or soil-gas probes. Within the trenches, anomalies are generally greater than 100 ppt.

Area B shows two large conductivity anomalies (Appendix A). The large anomaly in the northwest portion of the grid is caused by the burning cage. The second anomaly in the center of the grid is due to subsurface materials and has a maximum value of 46 mmhos/m. No in-phase component is available for Area B.

For the purpose of identifying metallic objects, the absolute magnitude and sign (positive or negative) of quadrature and in-phase measurements are generally not significant. Metallic objects cause strong disturbances in the induced electromagnetic field, which are complex and have a negative component. The fact that both quadrature and in-phase components of the field are high and often negative indicates that there is abundant metallic debris within the trenches.

4.3 MAGNETOMETER/GRADIOMETER

Base station measurements of total magnetic field were collected at a location east of the survey grid (Figure 2). A faulty cable connection in the base station magnetometer resulted in a partial loss of base station data on May 8, 1991, and a total loss of base station data on May 9, 1991. The available base station readings show a similar diurnal fluctuation (Figure 5) with declining field strength in the morning, reaching a minimum around 11 a.m., and increasing again through the afternoon. Total field strength fluctuations are on the order of about 30 gammas, about a mean background field strength of approximately 59,950 gammas. The mean field strength was used to produce preliminary magnetometer anomaly maps during the field survey.

The raw uncorrected magnetometer data indicate background field strength of the landfill ranges between 57,822 and 54,533 gammas, with an average value of 55,959 gammas. Field strength in the trenched areas ranges from 100 to 1,000 gammas above or below the mean field strength. This is a large range in

the total field and suggests the presence of ferromagnetic material in the trenches.

The magnitude of the anomalies is much greater than the diurnal fluctuation in the earth's magnetic field. The magnetic field anomaly was calculated using the average diurnal fluctuation shown on Figure 5. An average correction was used since base station data were not available for measurements collected on May 9, 1991. The maximum estimated error in base station correction using a single curve is approximately ± 12 gammas, or 12% of the minimum anomaly. Average error is on the order of 3 gammas, or 3% of the minimum anomaly. Therefore, the relative error in the calculated anomaly is estimated at $<5\%$. The total field anomaly is presented in Appendix B as a contour plot. The anomaly values range from -1,400 to 1,800 gammas, and appear as well defined linear anomalies that correspond to the trenches. The continuity of the negative and positive portions of the anomaly suggests extensive, well defined magnetic targets. Trenches 2, 4, and the north end of Trench 1 have a similar anomaly pattern: negative to the northeast and positive to the southwest. Three high intensity anomalies are present within the general linear anomaly corresponding to Trench 4. The other trenches appear as single anomalies. Trench 3 has a lower anomaly magnitude with scattered anomalies of 500 gammas or less. The southern portion of Trench 1 shows the highest anomaly magnitude ($\pm 1,500$ gammas) with the negative portion to the north and positive portion to the south.

Localized anomaly peaks are present within the overall anomaly in the trench areas. These peaks occur on the positive portion of the anomaly. The negative portion of the anomaly is somewhat uniform along the strike of the trench. A diagnostic feature of magnetic anomalies is the cross-over from negative to positive anomaly, which generally corresponds to the center or edge of a magnetic target. The location of the major cross-overs consistently corresponds to the strike of the trenches and suggests that the trenches contain abundant metallic debris throughout the entire trench and act as a single magnetic feature.

Gradiometer measurements are presented in Appendix B as a contour plot. The vertical gradient of the total magnetic field was calculated based on the difference in field strength between the two sensors, divided by the separation distance. Gradients range from +1,000 to -1,000 gammas/ft. The highest gradients generally correspond to areas of high total field.

4.4 GROUND-PENETRATING RADAR

GPR data were collected as continuous profiles and recorded on both paper and magnetic tape. Copied portions of selected profiles are included in Appendix C. In general, the GPR data was chaotic within the trench areas, and exhibited semicontinuous stratigraphic reflectors outside the trenches. Maximum subsurface penetration of approximately 20 ft was achieved outside the trench areas. A well defined stratigraphic reflector is present throughout much of the landfill at about 20 ft. As discussed previously, identification of characteristic parabolic or ringing patterns in the profiles was the primary focus of the GPR survey. The data in the trench areas show chaotic and high amplitude reflections. This made it difficult to identify and map small single targets, which could represent pipes or drums. It was, however, possible to identify larger targets and some trends in the depth to waste

materials between trenches. For example, some lines show progressively shallower depths to the chaotic trench reflections, indicating a dipping interface to the waste material. In addition, the boundaries of the trench were very distinct on the radargrams.

Further processing and identification of GPR targets was carried out by Williamson and Associates. Tape data were amplified and digitized by an image processing system, QMIPS (a tradename of Triton Technologies, Inc.), and subsequently displayed on a color monitor. Color displays have an increased dynamic range over black and white paper copies. Appendix C contains technical information regarding the processing and interpretation of the GPR data.

In general, all the GPR data have a relatively high amplitude and limited range. Processing and enhancement of the data improved the identification of high amplitude reflections, but the data still showed very high amplitudes. This may be partly due to time varying gains (TVG) applied to the data in the recording console. TVG balances the recorded amplitudes with respect to arrival time and produces more uniform and recognizable signals at greater arrival times. While this is beneficial for field recognition of deeper targets, it is not desirable for full range processing of the data.

A total of 253 targets were identified using the color enhanced display. Three categories of reflection character types were identified: parabolic/ringing, flat-lying/ringing, and chaotic. The targets were identified within these categories and their location and depth were plotted on a map. An average two-way travel time of 4 ns/ft was used to determine depth to a reflector. Table 1 summarizes the number of targets identified within each depth and character category. The majority of targets were identified at depths of 5 to 10 ft.

Table 1. Ground-Penetrating Radar Target Summary.

Type	Depth (ft)			
	0 to 3	3 to 5	5 to 10	>10
Parabolic/ringing	12	39	51	18
Flat-lying/ringing	5	21	53	15
Chaotic	4	6	24	5
Total	21	66	128	38

5.0 INTERPRETATION

No single data set provided sufficient information to fully characterize the materials within the trenches. All three data sets were generally saturated by the trenches due to the abundance of metallic debris. Therefore, this limited the ability of the techniques to distinguish discrete targets within the trench. The opinion is that further processing of the data using two dimensional band pass filters or Fourier analysis would not

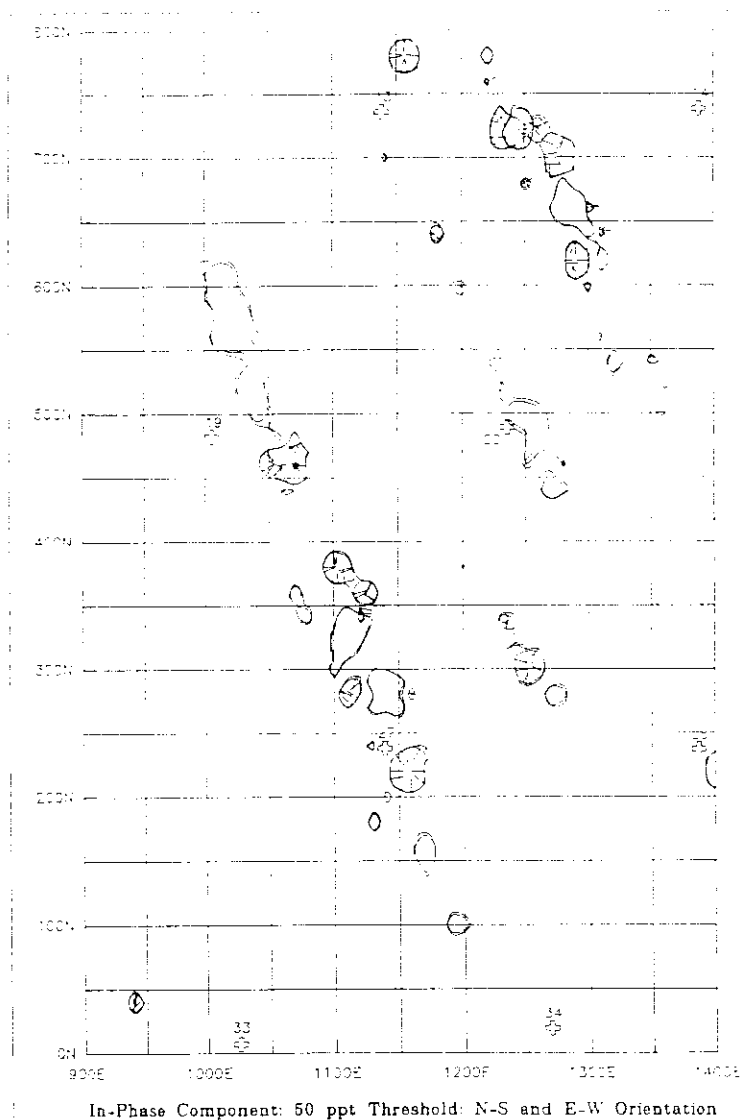
significantly change the interpretation of the anomalies since the data is so dominated by the trenches. Interpretations and recommendations are based on composite analyses of the various data sets using overlays of the contoured results. The objectives of the interpretation was to identify locations having a high probability of containing high concentrations of metal. These locations were identified based on the following criteria:

- EMI Quadrature anomaly >20 mmhos/m and >20 ft diameter
- EMI In-phase anomaly >50 ppt and >20-ft diameter
- Total magnetic field anomaly >300 gammas and >40 ft diameter
- Total magnetic field gradient >50 gammas/ft and >20-ft diameter
- High amplitude, well-defined GPR targets within the threshold areas.

The contour plots provided in Appendices A, B, and C were re-plotted using the above criteria as thresholds and overlays were examined. The threshold limited the displayed contour values rather than apply an explicit filter to the data. Figure 6 shows the areas corresponding to the quadrature and in-phase criteria. Figure 7 shows the areas corresponding to the total field and total field gradient criteria. Note that the cross-over point of the magnetometer profiles does not correspond to the location of either magnetometer or EMI anomalies. These cross-over points are more dependent on the axis of the edge of the trench, which acts as the axis of the primary target. These figures show that high amplitude anomalies are present over areas up to 5,000 ft² in size.

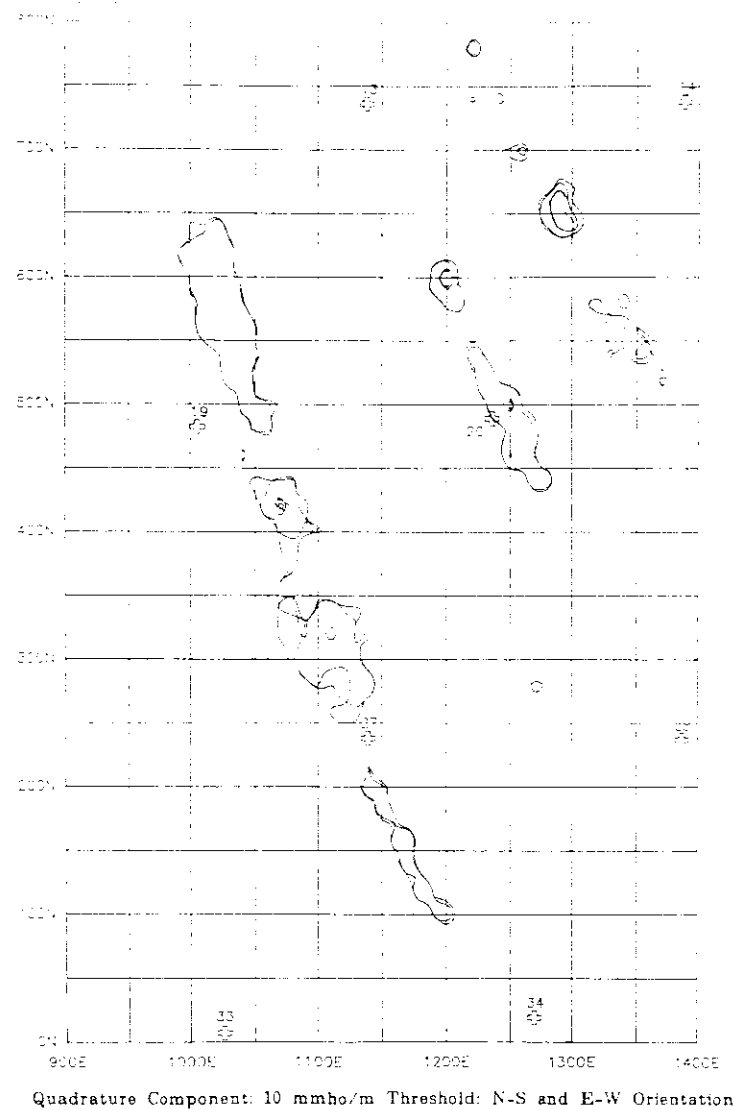
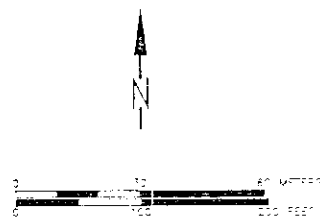
Using the above criteria, ten areas were selected in Area A as having a high probability of containing concentrations of metallic objects. One location was selected in Area B. The exact coordinate was selected primarily based on the GPR criteria for high amplitude well defined targets within the EMI and magnetometer anomaly areas. Table 2 summarizes the anomaly areas and recommended test pit locations. Appendix C contains the raw GPR data profiles across these test pit locations. The exact nature of the target areas shown on Table 2 cannot be determined, nor is it possible to determine a likelihood that these areas contain buried drums. Excavation will be required to positively identify the materials at these locations.

For the purpose of clarification of possible future excavation at the landfill, areas selected are referenced to the field coordinates established prior to the survey. At the time of this report, the field grid is still intact at the site. All coordinates will be converted to NAD 83 Coordinates prior to integration into the HEIS database.



LEGEND:

Soil Gas Probe



6/28/91 913-1249\J5017

Figure 6. Electromagnetic Induction Anomalies with Threshold.

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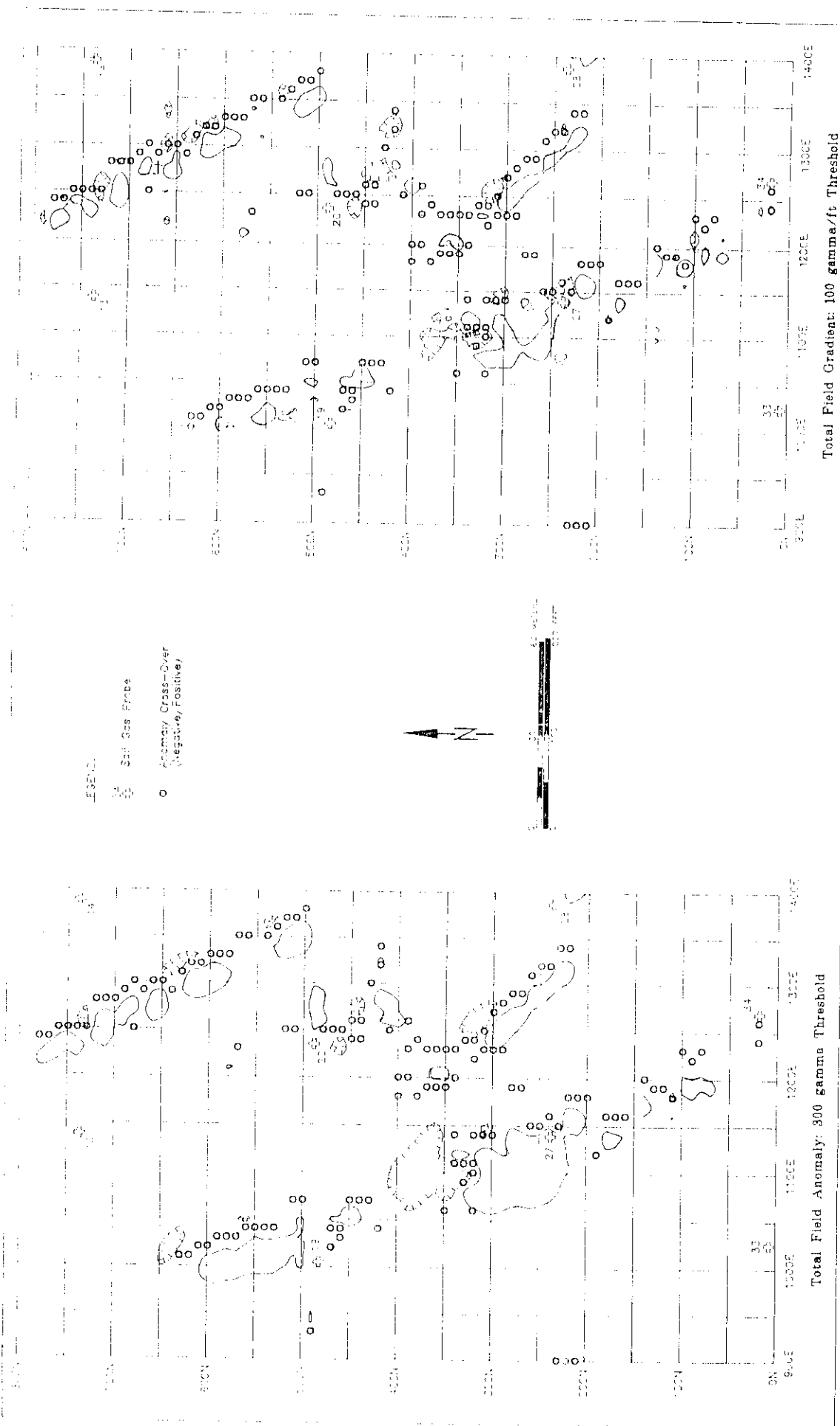


Figure 7. Magnetometer Anomalies with Threshold.

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Table 2. Composite Geophysical Anomaly Locations and Recommended Test Pit Locations.

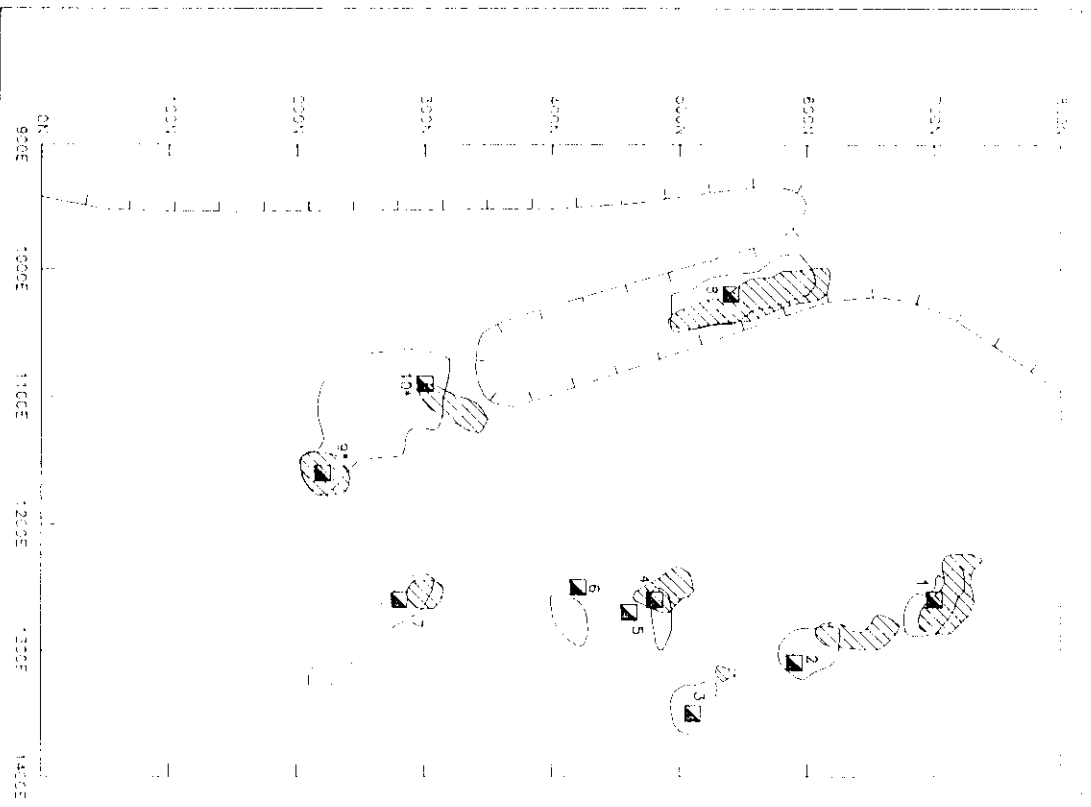
Anomaly/Test Pit Number	Location	GPR Target Depth/Character
1	(700N,1260E):(710N,1270E)	5 to 8 ft, parabolic
2	(590N,1310E):(600N,1320E)	5 to 8 ft, parabolic
3	(510N,1350E):(520N,1360E)	8 to 10 ft, ringing
4	480N,1260E):(470N,1270E)	8 to 10 ft, parabolic
5	(460N,1270E):(470N,1280E)	<5 ft parabolic
6	(420N,1250E):(430N,1260E)	8 to 10 ft, parabolic
7	(280N,1260E):(290N,1270E)	5 to 8 ft, ringing
8	(540N,1020E):(530N,1030E)	<5 ft parabolic
9 (Trench 1)	(300N,1090E):(310N,1100E)	5 ft chaotic
10 (Trench 1)	(220N,1160E):(230N,1170E)	< 5 ft chaotic
11 (Area 8)	(1400N,1500E):(1410N,1490E)	5 to 8 ft, ringing

6.0 RECOMMENDATIONS

Based on the integrated interpretation of all geophysical anomalies detected with EMI, magnetometer, and GPR surveys at the Horn Rapids Landfill, the limited test pit program is recommended to further characterize the anomalous areas identified on Table 2. Figure 8 shows the recommended locations for test pit excavation at the Horn Rapids Landfill. Excavating a 12 ft by 12 ft pit to a depth of 20 ft or until encountering undisturbed fill or natural materials is recommended to include additional GPR traverses across each test pit location prior to excavation. This may enable further GPR signatures to be positively identified during excavation, and used for future investigations at the Hanford Site. Excavated materials should be identified and logged as the excavation proceeds and appropriate health and safety monitoring should be performed. Encountering drums containing large amounts of hazardous materials is not anticipated, based on the history of the landfill and the results of previous groundwater and soil-gas investigations. If no drums are encountered during excavation of the initial test pits, it is recommended that no further excavations be undertaken and that appropriate closure actions be initiated.

2011-03-09

Area A



TEST PIT	NORTH	EAST	DEPTH
1	700	1280	12-15 ft
2	550	1270	12-15 ft
3	570	1380	12-15 ft
4	450	1280	12-15 ft
5	480	1270	< 12 ft
6	470	1280	12-15 ft
7	320	1280	12-15 ft
8	340	1300	< 12 ft
9	320	1180	< 12 ft
10	300	1090	< 12 ft
11	1400	1480	12-15 ft

* Not recommended for initial test pit program.

Area B

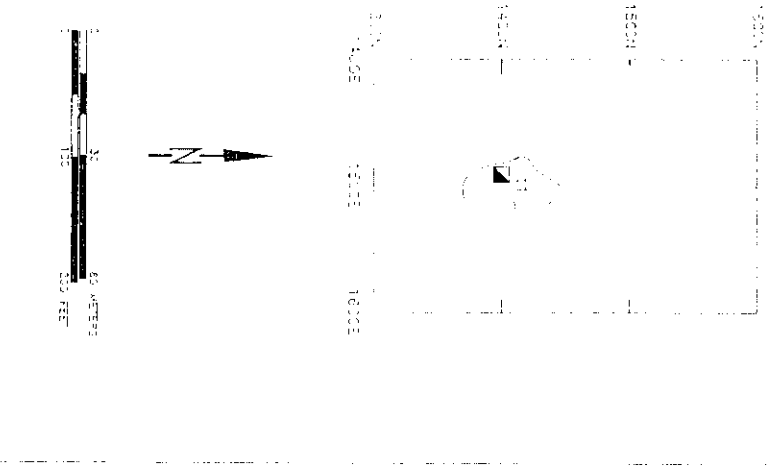


Figure 9. Recommended Test Pit Locations.

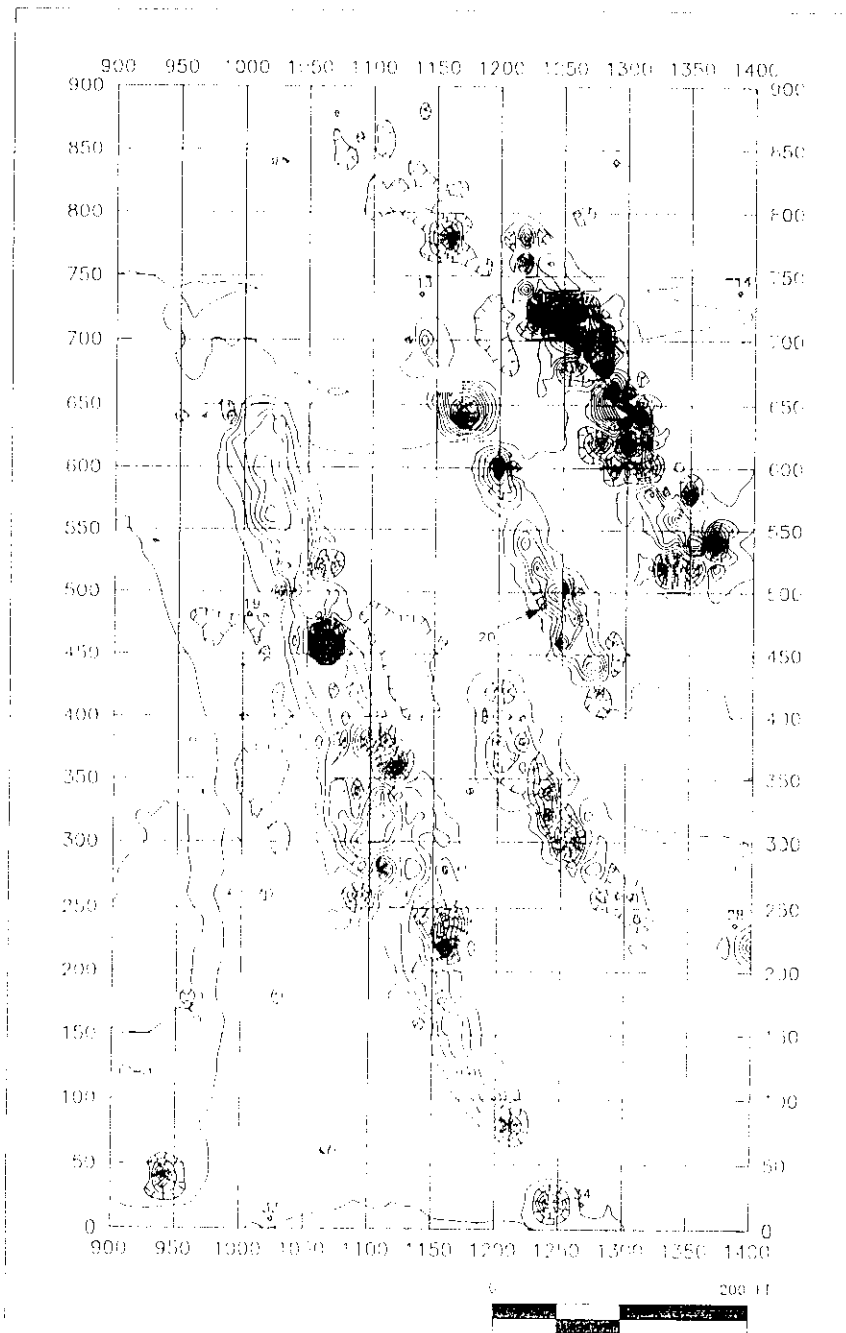
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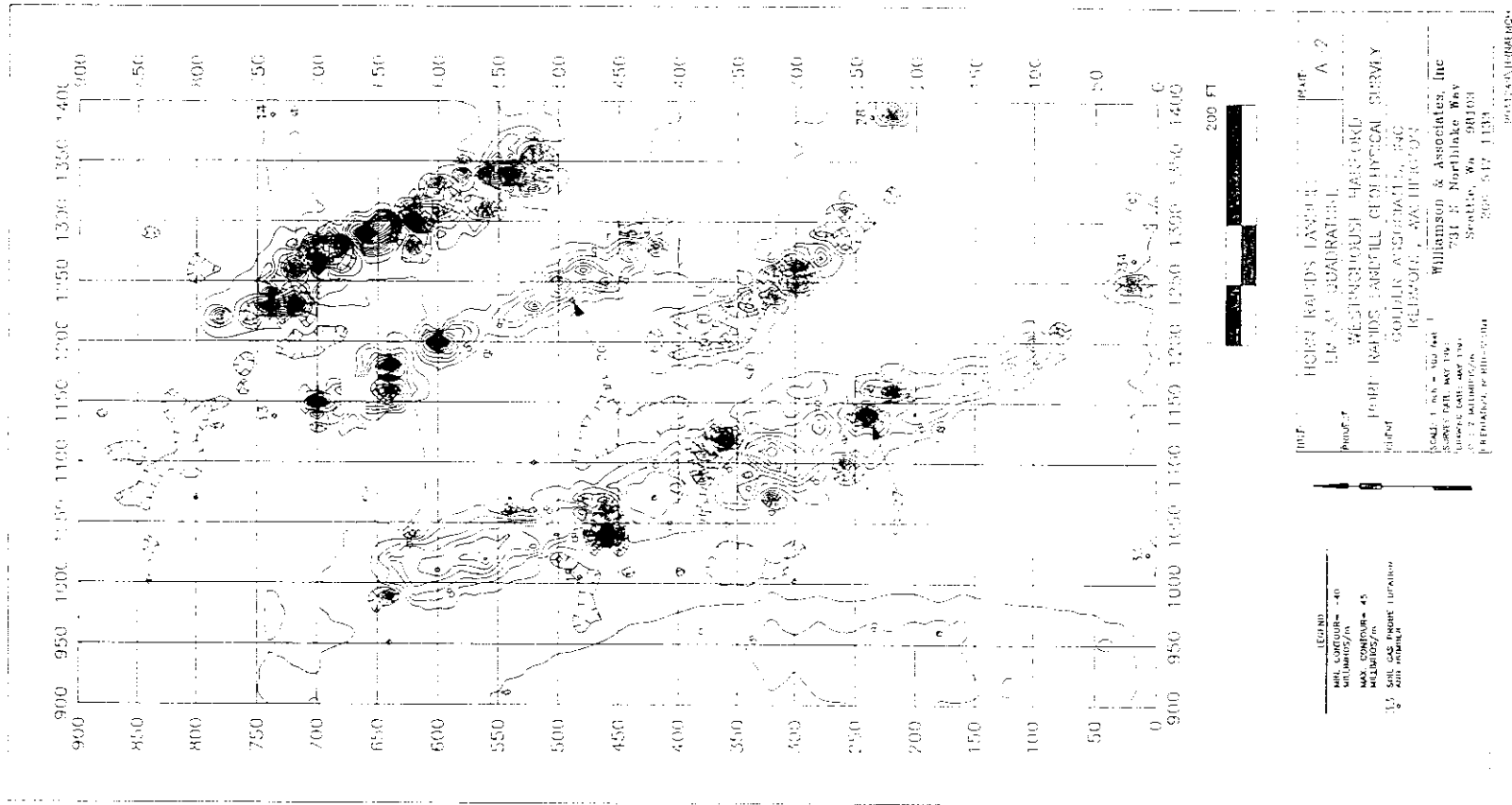


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FEET
MAX. CONTOUR = 40
FEET
3.15 SOIL GAS PROBE LOCATION
AND NUMBER

DATE: HORN RAPIDS LANDFILL
PROJECT: EM 3112 RADIATION
WETTERHOUSE HATCH ORD
HORN RAPIDS LANDFILL GEOPHYSICAL SURVEY
CLIENT: GOLDER ASSOCIATES, INC.
REDMOND, WASHINGTON
Williamson & Associates, Inc.
791 N. Northlake Way
Seattle, Wa 98103
206 547-1133

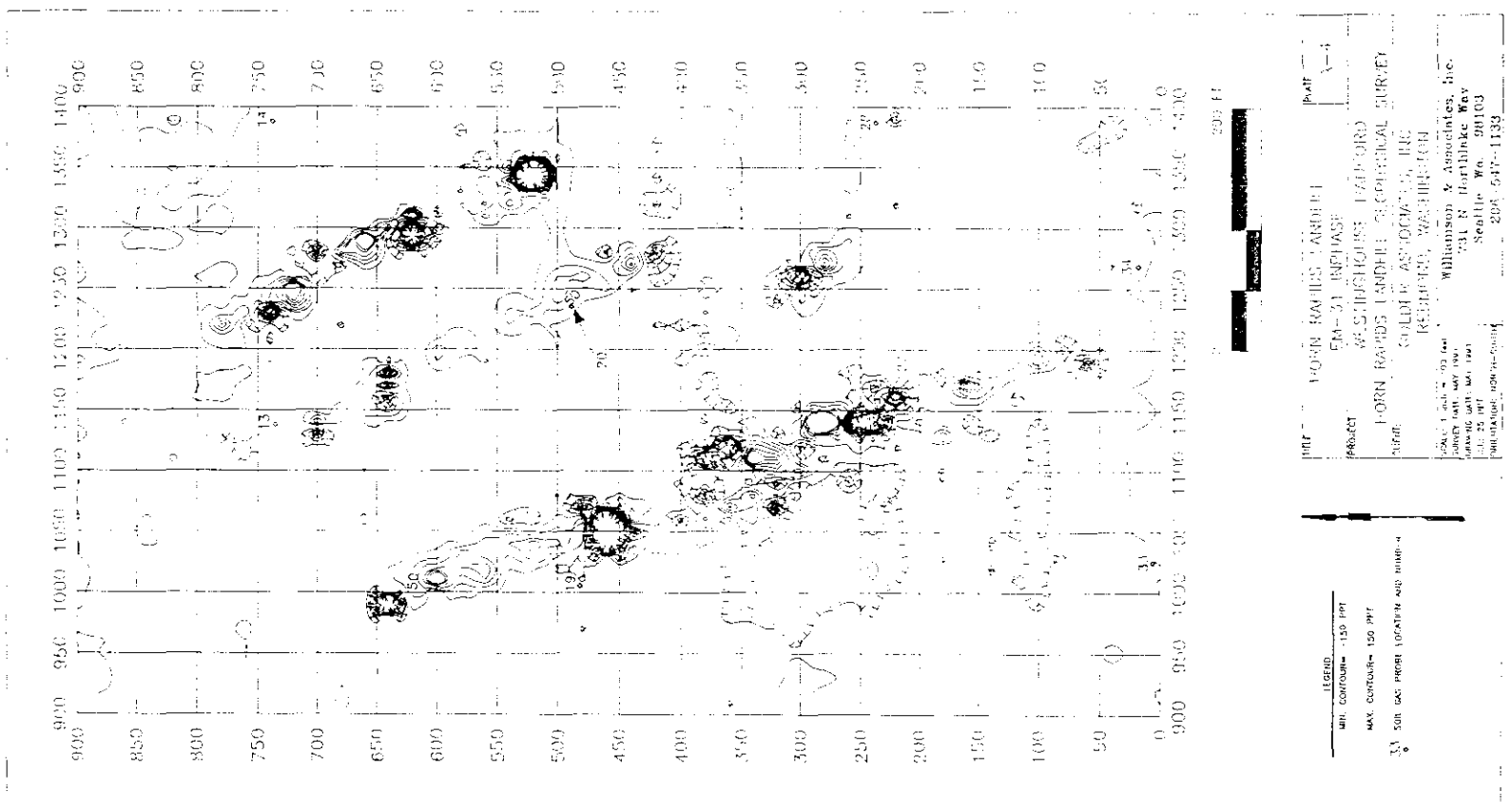
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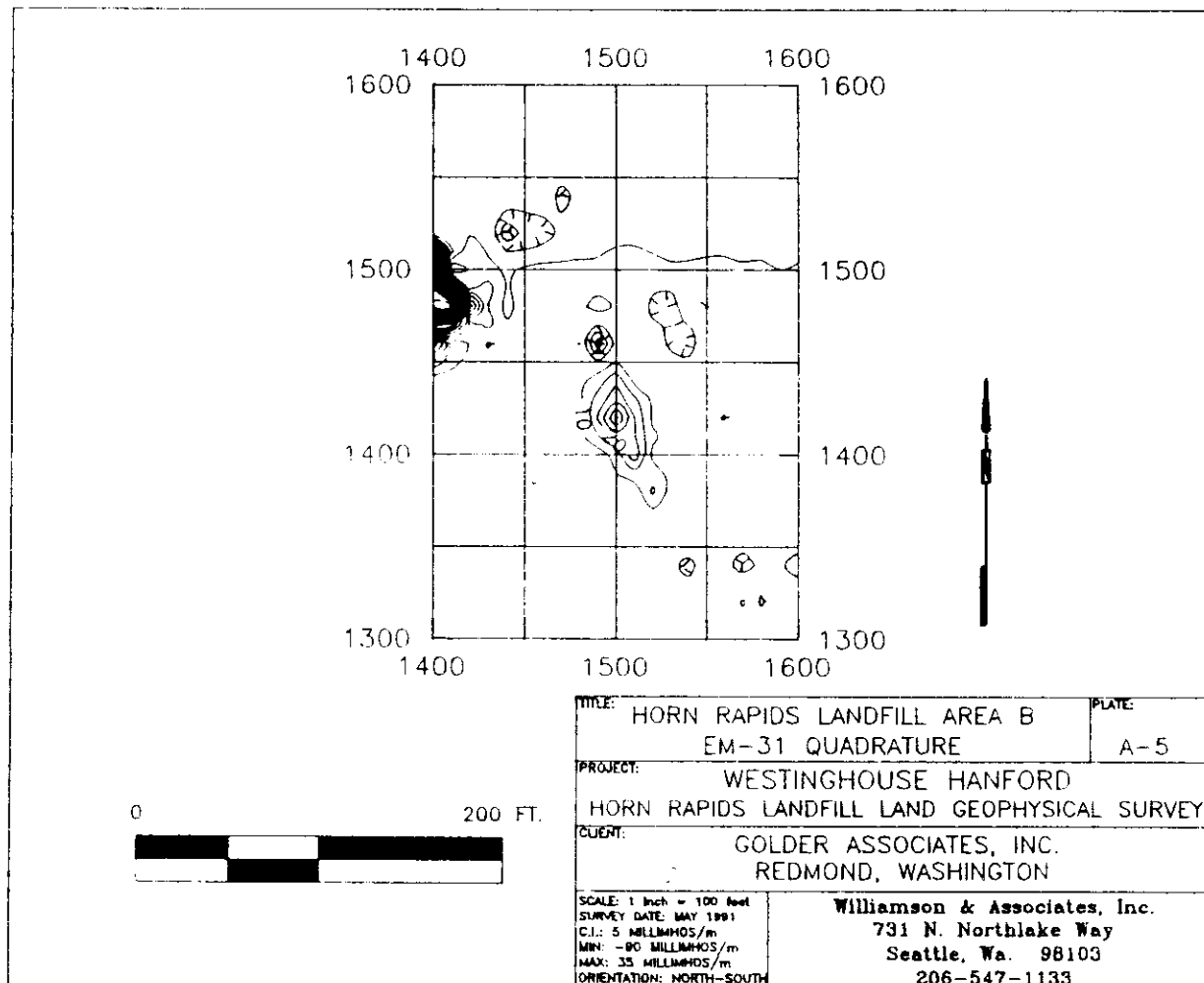
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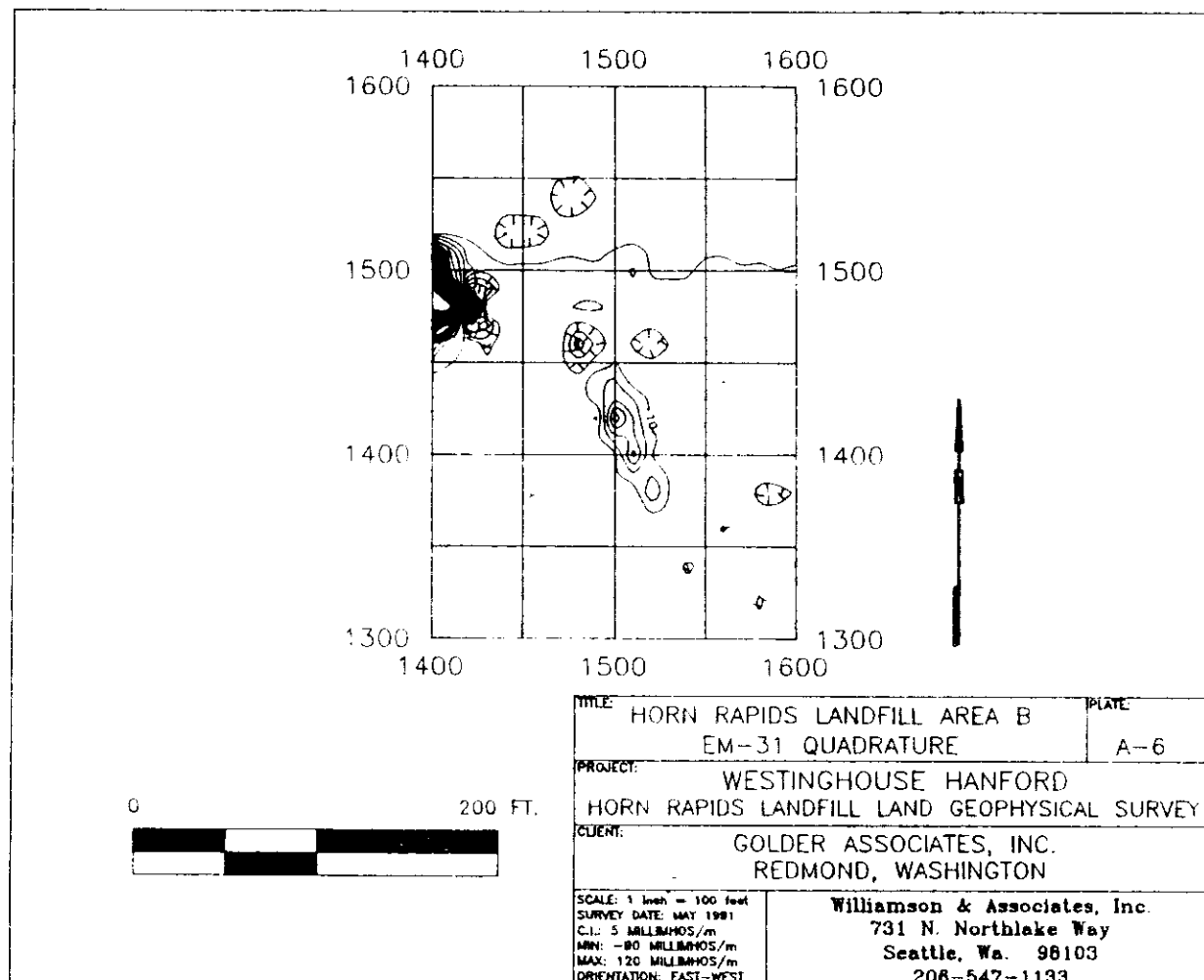
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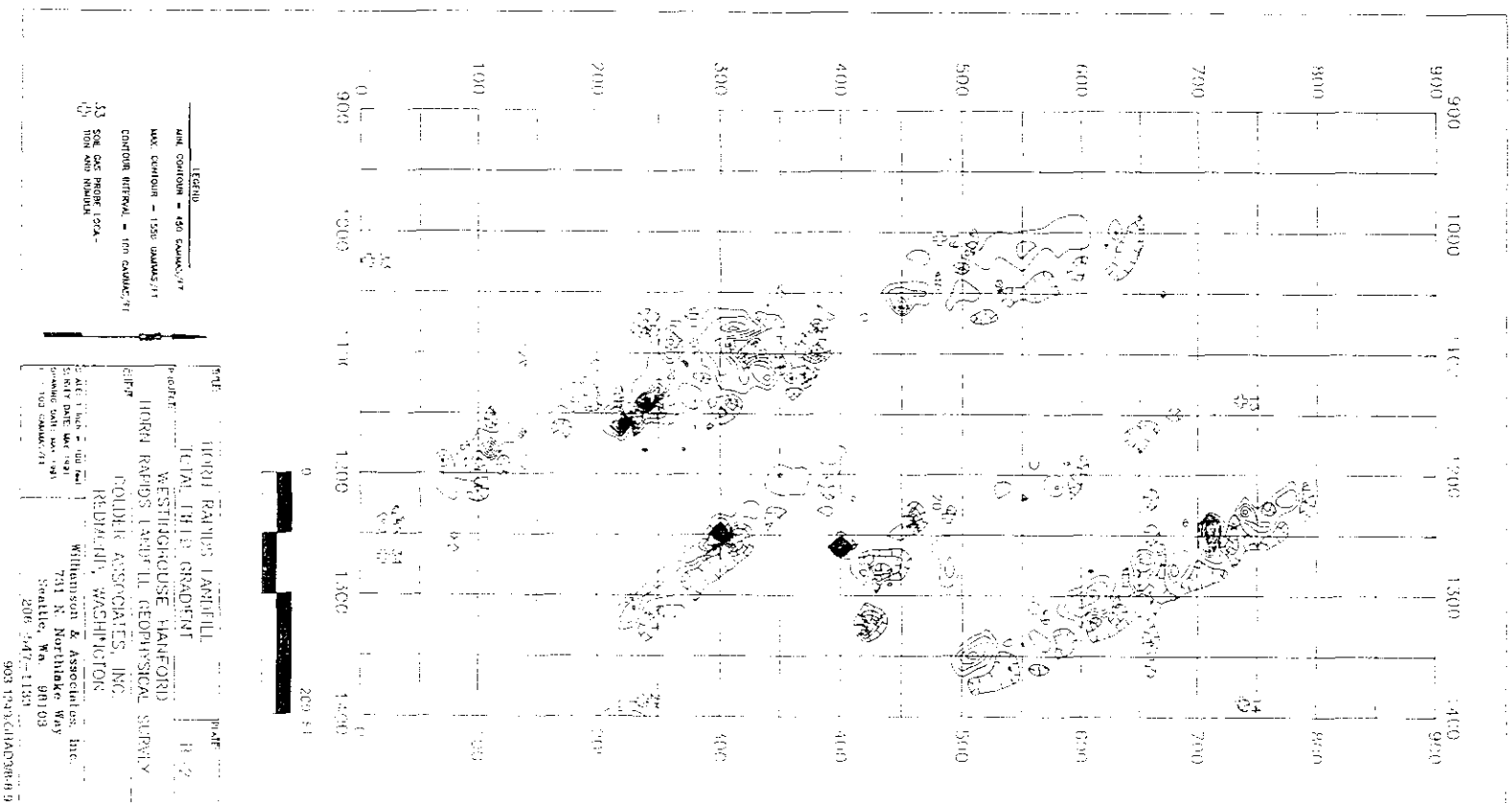
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APPENDIX B
MAGNETOMETER/GRADIOMETER RESULTS

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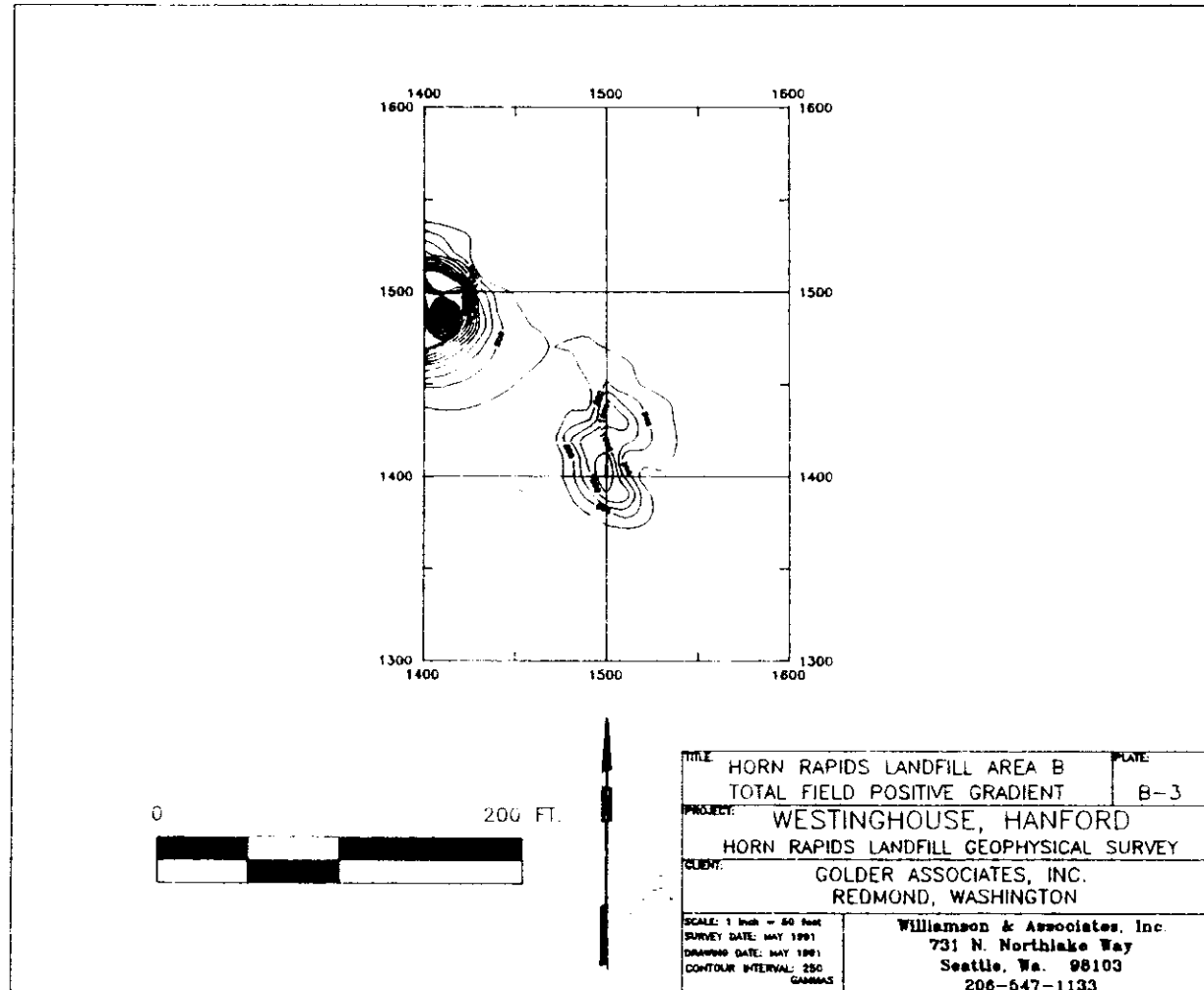


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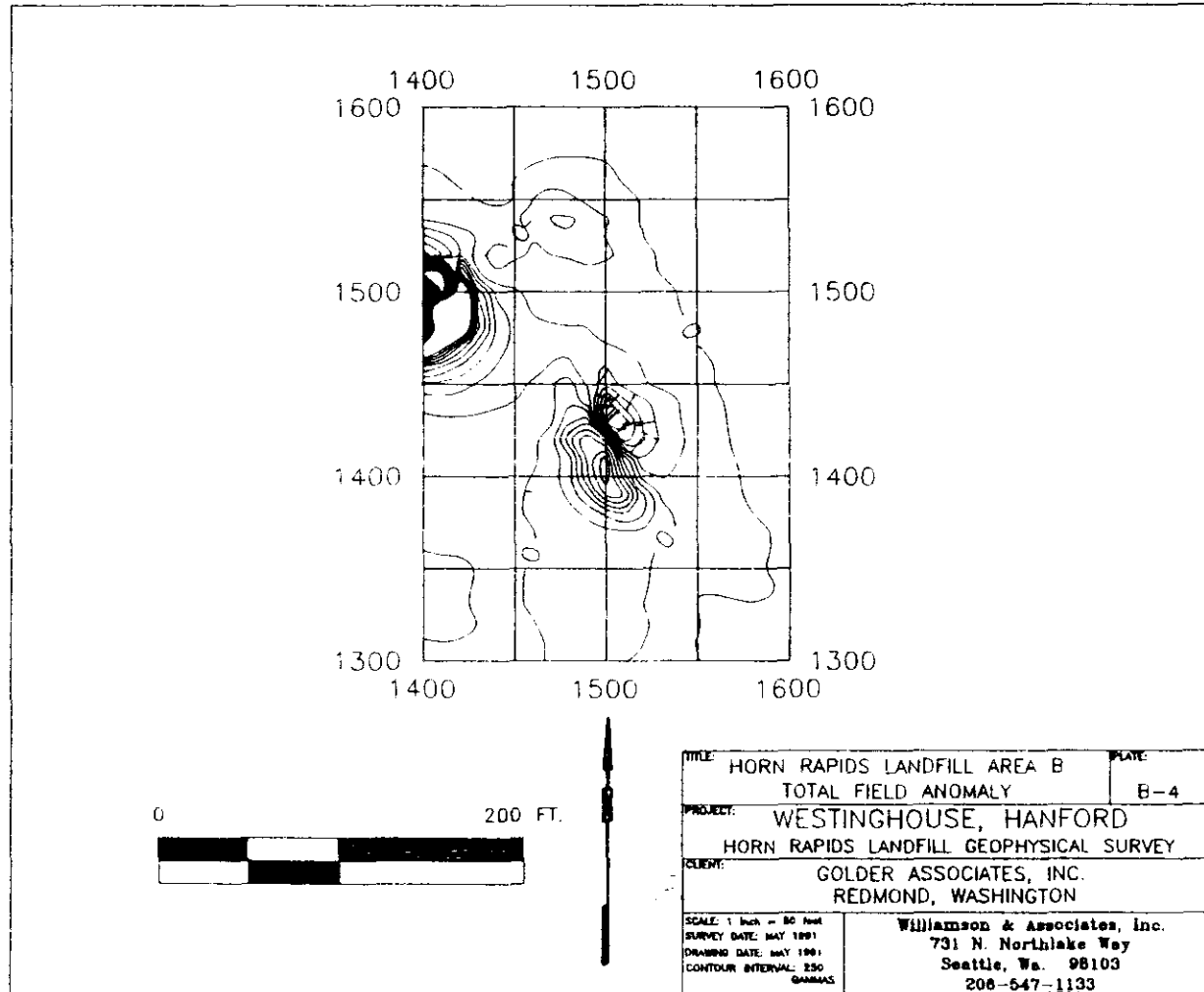


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APPENDIX C
GROUND-PENETRATING RADAR RESULTS

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GPR DATA ACQUISITION SYSTEMS

During the field operations the GPR data were acquired on both a graphic analog display recorder and a magnetic digital recorder. On both data sets distance traveled along each survey line was indicated by a mark at 5-ft intervals. In addition, voice annotation was placed on the digital tape at the start and end of each line and the number on the tape counter was logged for these positions.

DIGITAL TAPE RECORDER SPECIFICATIONS:

Recording System	Rotary-head DAT
Manufacturer/Model	Panasonic/SV-MD1
Sampling Frequency	48 KHz
Frequency Response	10 Hz- 22 kHz +/- 1db
Dynamic Range	> 87db
Signal/Noise	> 88db

DIGITAL DATA PROCESSING (Q-MIPS)

The Q-MIPS system generates a color display of the GPR time series data and displays this information on a high resolution video monitor and also outputs to a HP Paintjet to produce a permanent hard copy of the final processed section.

The digitally recorded GPR data were input to the Q-MIPS processing system where they were digitally stored on an optical disc (8 bits, 96db) prior to data processing. A number of processing options are available, and were tried, to enhance the GPR data.

The data were sampled at 200 kHz which results in producing 13 samples/pixel for each of the 1024 pixels displayed for each sweep. The selected value for each pixel, which represents signal amplitude and is displayed as a color, can be either the maximum, the average, or the RMS value of the 13 samples. Once this selection has been made, a histogram is computed for 10 radar pings that shows the distribution of the signal amplitude for the data. The 256 available colors can then be stretched over the range of data to provide the maximum contrast between reflections and to emphasize subtle changes in reflectivity of small targets. Additional enhancement of the data was accomplished by entering a threshold level which also spreads the data out over the available colors, above the selected threshold value, and tends to "brighten" subtle features in the radar image. Additional filtering was applied, if needed, to reduce some of the background noise.

All GPR data was transferred to the optical disk drive on the Q-MIPS system and processed as described above. As the data were displayed on the high resolution video monitor features of interest were identified and their position noted. In many cases it was necessary to try a number of threshold values and various filters in an attempt to detect discrete reflectors, such as possible drums, in areas of high background reflectivity.

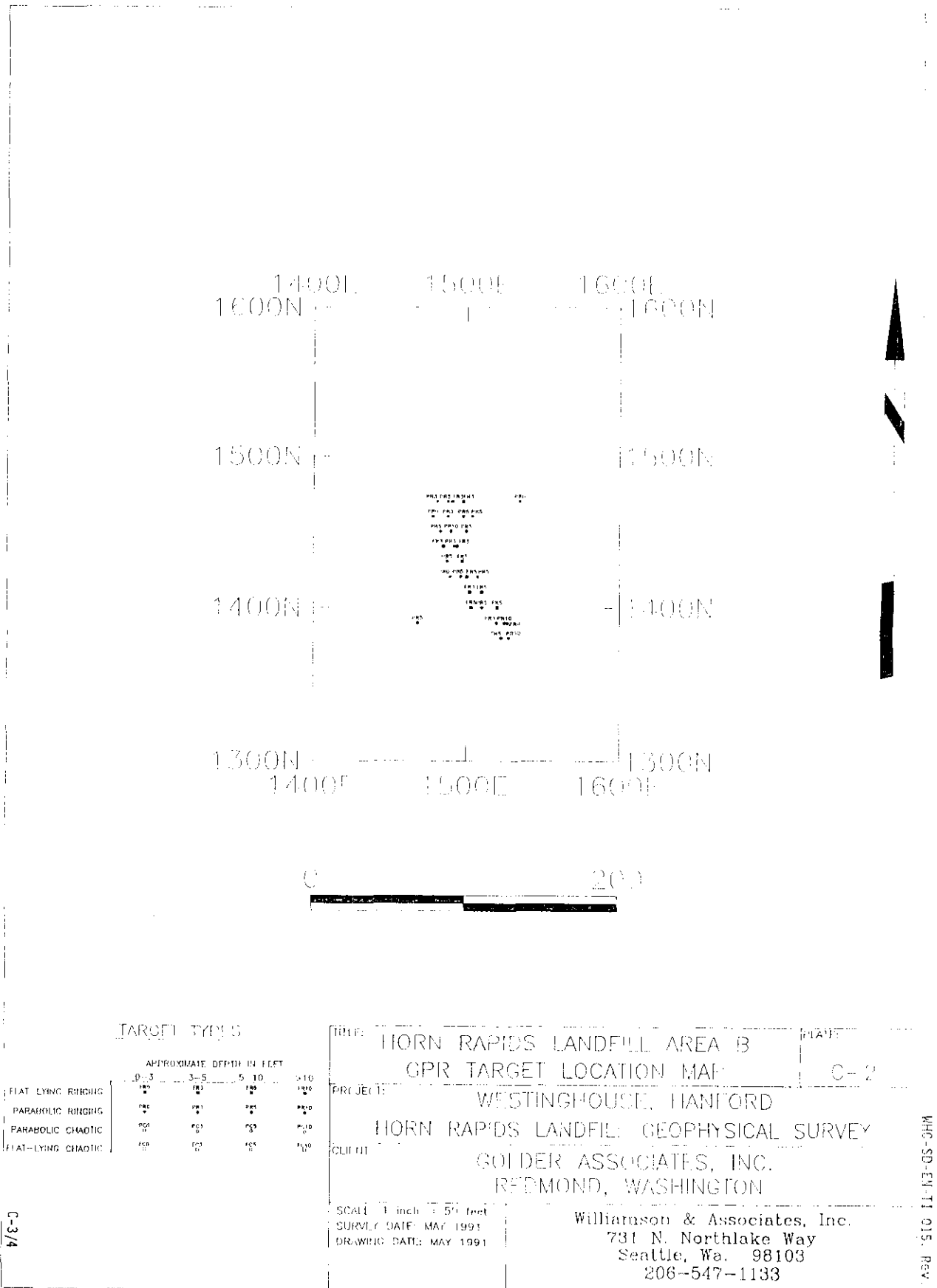
A list of targets, generated during the above process, was then plotted on a scaled map of the survey area. These maps were then overlaid on the magnetometer maps and the terrain conductivity maps to help identify features that appeared to have the highest probability of being buried drums.

DATA PROCESSOR SPECIFICATIONS:

Data Processor	Q-MIPS
Manufacturer	Triton Technology, Inc.
Computer	16MHz 80386
	20MFLOPS, 10MIPS RISC Array Processor
	40 MHz, 6 MIPS Graphic Processor
Mass Storage	3.5 in., 1.44 MB floppy drive
	300 MB SCSI hard drive
	1.2 GB (2) optical drive
Image Processing	Thresholding
	Histogram Equalization
	Spatial Filters
	FFT (transform domain) filters
	Hough Transform
	Depth-corrected reflection display
Image Analysis	Object width, length and height
	Object position
	Pixel intensity measurement
	Zoom-in of imagery or target

GPR RECORDS

Vellum photocopies of the raw GPR records are available in a separate data appendix and are not presented in this report.



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HORN RAPIDS LANDFILL GPR TARGET MAP
AREA A

<u>LINE</u>	<u>LOCATION</u>	<u>TYPE</u>
200N	1165	P5
200N	1142-1145	R3
200N	1110-1115	R10
200N	1116	P3
210N	1108	PC0
210N	1143-1146	R3
210N	1170-1180	FC3
220N	1146-1150	R5
220N	1145-1150	R10
230N	1101	P5
230N	1130	P5
230N	1150	P5
230N	1169	PC5
230N	1310	P3
240N	1300-1304E	R3
240N	1315-1320	R3
240N	1152-1160	PC5
240N	1148	P5
240N	1119	P3
240N	1097-1100	FC5
250N	1142	P5
250N	1328	P5
260N	1273	P5
270N	1304	P3
270N	1290	P5
270N	1296-1300	R3
270N	1275	P5
270N	1142	P3
280N	1120-1123	R5
280N	1148	P3
280N	1153-1160	FC5
280N	1165-1170	FR5
280N	1264	P0
280N	1280	P10
280N	1293	P3
290N	1057	P3
290N	1107-1110	R5
290N	1146-1150	R5
290N	1146-1150	R5

(HRL GPR TARGET MAP - AREA A, CONTINUED)

<u>LINE</u>	<u>LOCATION</u>	<u>TYPE</u>
300N	1253-1255	PC5
300N	1260-1263	FC5
310N	1075-1080	R5
310N	1130-1133	R3
310N	1250-1260	R5
320N	1273-1275E	R0
320N	1247-1250	R3
320N	1244	P5
320N	1145-1150E	R3
320N	1108	PC5
320N	1100-1104	R3
330N	1077-1080	R3
330N	1082-1084	FC5
330N	1097-1100	R3
330N	1150	PC5
330N	1060	P3
330N	1230-1235	R5
340N	1227-1230	R5
340N	1203-1210	R5
340N	1140-1210	FC5
340N	1133	P5
340N	1094	P5
350N	1118	P5
350N	1202-1130	R5
350N	1205	P3
350N	1205-1210	R5
480N	1337	P0
480N	1260-1270	R5
490N	1230	P3
500N	1023E	P0
500N	1026E	R5
500N	1030E	P10
500N	1047E	R5
500N	1053E	P0
500N	1066E	R5
500N	1230-1235	R5
510N	952	P10
510N	956	P10
510N	1032E	P5
510N	1023E	R5
510N	1018E	R3
510N	1226	P3

(HRL GPR TARGET MAP - AREA A, CONTINUED)

<u>LINE</u>	<u>LOCATION</u>	<u>TYPE</u>
510N	1242E	P5
510N	1355	PC3
510N	1361	PC10
510N	1366-1368	FC10
520N	1023E	R3
520N	1027E	R5
520N	1046E	P3
520N	1361	PC5
520N	1340-1344	FC5
520N	1340	P10
520N	1242	P0
520N	1225	P10
530N	1070E	P5
530N	1055E	R5
530N	1038E	P3
530N	1030E	R3
530N	1027E	P5
530N	1344-1350	FC10
540N	1006E	P3
540N	1018E	R5
540N	1022E	R5
540N	1027E	R5
540N	1050E	R5
540N	1061E	R5
540N	1056E	R10
540N	1360-1350	FC5
540N	1335-1340	FC5
540N	1218	P5
540N	1202-1205	FC5
540N	1206-1210	FC5
550N	1050	P10
550N	1217	P10
550N	1225-1228	FC10
550N	1334-1340	FC5
550N	1359	P10
550N	1361	PC3
560N	1006	P3
560N	1014	R10
560N	1040	R5
560N	1053	P5
560N	1060	P5
560N	1359	PC0

(HRL GPR TARGET MAP - AREA A, CONTINUED)

<u>LINE</u>	<u>LOCATION</u>	<u>TYPE</u>
570N	1048E	P5
570N	1033E	R10
570N	1021	R10
570N	1007	P5
570N	1213	P5
570N	1316-1323	R0
570N	1309	P5
580N	1000E	P5
580N	1010E	P5
580N	1330E-1348E	FC5
580N	1220	P3
580N	1216	P5
590N	1040E	R5
590N	1033E	R5
590N	1015E	R5
590N	1328	P5
590N	1337	PC5
590N	1308-1310	R10
590N	1310-1317	R3
590N	1248	P10
590N	1222	PC3
600N	1000E	P3
600N	1009E	P5
600N	1015E	R5
600N	1027E	R10
600N	1044E	P10
600N	1329	PC0
600N	1312	P5
600N	1298	P3
610N	992	R5
610N	983	R3
610N	1020	P3
610N	1034	R0
610N	1038	R10
610N	1303	P0
610N	1302-1310	FC5
610N	1328	FC10
610N	1334	PC0
620N	978	P3
620N	986	P5
620N	1040E-1043E	R5
620N	1050	P3

(HRL GPR TARGET MAP - AREA A, CONTINUED)

<u>LINE</u>	<u>LOCATION</u>	<u>TYPE</u>
630N	1042E	P0
630N	1030E	R5
630N	1285-1290	R0
630N	1290-1294	R10
630N	1302	PC3
640N	987E	P3
640N	995E	P5
640N	996E-1003E	R5
640N	1010E	P3
640N	1028E	P10
640N	1280-1288	R3
640N	1290-1294	R5
650N	989E	PC5
650N	1292-1296	R10
650N	1297-1299	FC10
660N	1292	P0
660N	1272	P3
660N	1270-1275	R10
670N	1275-1280	R5
670N	1280-1290	FC5
680N	1267	P5
680N	1275-1280	FC5
690N	1236E	P10
730N	1240-1245E	R10
730N	1249E	P3
740N	1228	P10
740N	1252E	PC5
750N	1230-1235	R3
750N	1243-1238	R5
1050E	445N	P3
1050E	450N	R5
1050E	454N	P3
1050E	457N	P5
1050E	492N	R3
1050E	482N	R5
1060E	433N	R3
1060E	455N	P3
1060E	460N	P5
1060E	490N	R5
1060E	502N	P5

(HRL GPR TARGET MAP - AREA A, CONTINUED)

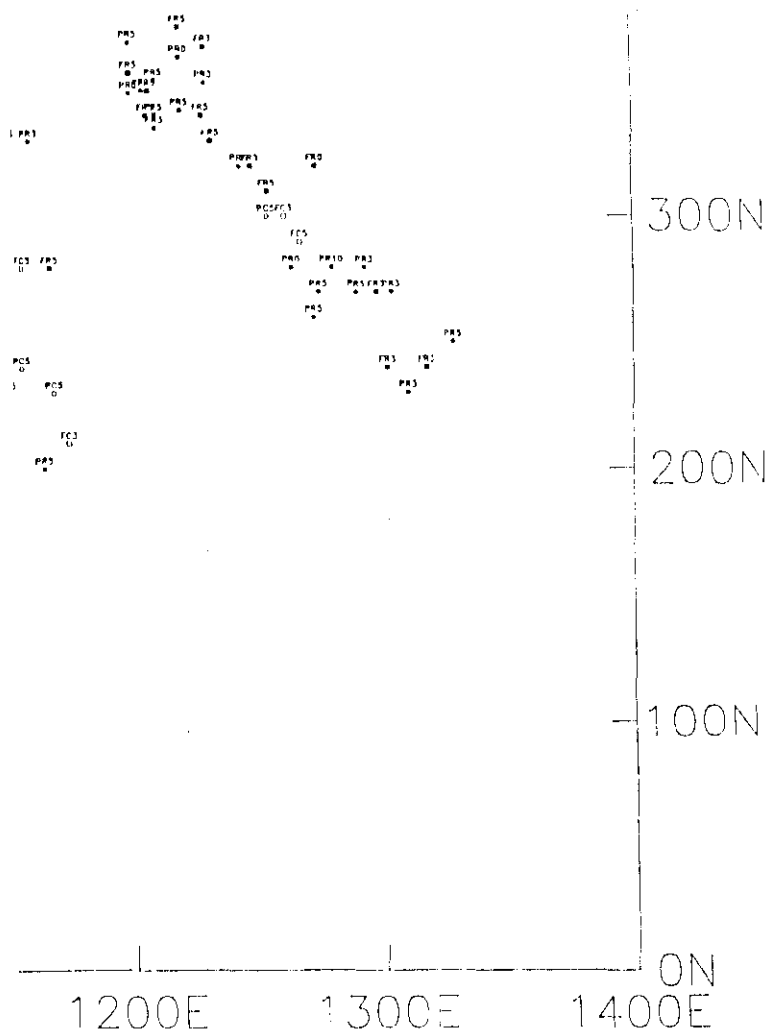
<u>LINE</u>	<u>LOCATION</u>	<u>TYPE</u>
1065E	419N	R5
1065E	439N	R5
1065E	446N	P5
1065E	452N	R5
1065E	473N	P0
1070E	483N	P10
1070E	470N	P3
1070E	478N	R5
1070E	448N	P3
1070E	441N	P5
1075E	413N	P5
1075E	419N	R3
1075E	427N	P5

1200E 1300E 1400E ON

TITLE: HORN RAPIDS LANDFILL GPR TARGET LOCATION MAP		PLATE: C-1
PROJECT: WESTINGHOUSE, HANFORD HORN RAPIDS LANDFILL GEOPHYSICAL SURVEY		
CLIENT: GOLDER ASSOCIATES, INC. REDMOND, WASHINGTON		
SCALE: 1 inch = 50 feet SURVEY DATE: MAY 1991 DRAWING DATE: MAY 1991	Williamson & Associates, Inc. 731 N. Northlake Way Seattle, Wa. 98103 206-547-1133	

WHC-SD-EN-TIE-015

Rev. 0



TITLE: HORN RAPIDS LANDFILL GPR TARGET LOCATION MAP	DATE: C--1
PROJECT: WESTINGHOUSE, HANFORD HORN RAPIDS LANDFILL GEOPHYSICAL SURVEY	
CLIENT: GOLDER ASSOCIATES, INC. REDMOND, WASHINGTON	
SCALE: 1 inch = 50 feet SURVEY DATE: MAY 1991 DRAWING DATE: MAY 1991	Williamson & Associates, Inc. 731 N. Northlake Way Seattle, Wa. 98103 206-547-1133

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300N

200N

100N

0N

900E

1000E

1100E



TARGET TYPES

	APPROXIMATE DEPTH IN FEET			
	0-3	3-5	5-10	>10
FLAT-LYING RINGING	FR0	FR1	FR2	FR3
PARABOLIC RINGING	PR0	PR1	PR2	PR3
PARABOLIC CHAOTIC	PC0	PC1	PC2	PC3
FLAT-LYING CHAOTIC	FC0	FC1	FC2	FC3

0

20



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900E 1000E 1100E
900N

800N |

700N

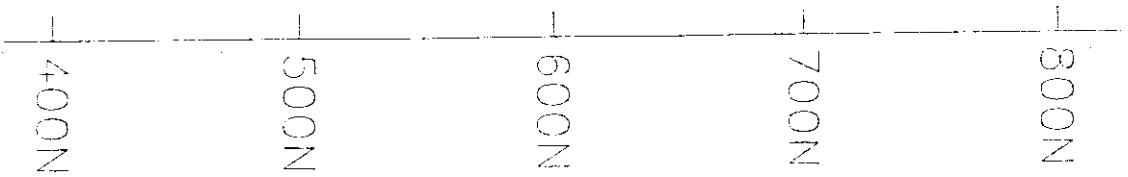
600N

500N | —

400N

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HORN RAPIDS LANDFILL GPR TARGET MAP
AREA B

<u>LINE</u>	<u>LOCATION</u>	<u>TYPE</u>
1200E	408N	PR5
1200E	390N	PR5
1200E	369N	PR5
1200E	357N	PR5
1200E	349N	PR5
1210E	335N	PR3
1210E	340N	FR5
1210E	354N	PR5
1210E	388N	FR10
1210E	400N	PR3
1210E	482N	PR0
1220E	415N	FR5
1220E	407N	PR5
1220E	343N	PR5
1220E	375N	FR5
1220E	363N	PR0
1220E	342N	PR5
1230E	353N	PR3
1230E	367N	FR3
1230E	390N	PR3
1250E	450N	PR5
1250E	457N	FR3
1250E	465N	PR5
1250E	488N	PR10
1260E	485N	PR10
1260E	458N	PR5
1260E	448N	PR5
1260E	428N	PR5
1270E	416N	FR0
1270E	452N	FR10
1270E	460N	PR10
1270E	417N	PR10
1280E	462N	PR5
1280E	458N	PR3
1280E	451N	FR5
1290E	450N	FR5
1290E	482N	PR0
1300E	471N	PR3
1300E	468N	PR3
1300E	433N	PR0

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(HRL GPR TARGET MAP - AREA B, CONTINUED)

<u>LINE</u>	<u>LOCATION</u>	<u>TYPE</u>
1380N	1528E	PR10
1380N	1523E	FR5
1390N	1527E	PR0
1390N	1525E	PR10
1390N	1527E	PR3
1390N	1468E	PR5
1400N	1503E	FR5
1400N	1510E	PR5
1400N	1520E	FR5
1410N	1510E	FR5
1410N	1502E	FR3
1420N	1489E	PR0
1420N	1496E	PR5
1420N	1500E	PR5
1420N	1507E	PR5
1430N	1497E	FR3
1430N	1487E	PR5
1440N	1485E	FR3
1440N	1492E	PR3
1440N	1494E	FR5
1450N	1500E	PR5
1450N	1490E	FR10
1450N	1983E	PR5
1460N	1478E	PR0
1460N	1488E	PR3
1460N	1498E	PR5
1460N	1504E	PR5
1470N	1535E	PR0
1470N	1498E	FR3
1470N	1491E	FR3
1470N	1488E	PR5
1470N	1481E	PR3

APPENDIX D
TECHNICAL PROCEDURES

9 3 1 2 7 1 2 0 0 1 0

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CONTENTS

TP-1.1-4, Ground-Penetrating Radar Surveying	D-3
TP-1.1-5, Electromagnetic Surveying (EM-31)	D-12
TP-1.1.7, Magnetometer Surveying	D-22

9 7 1 2 7 5 2 1 0 0 9

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INFORMATION ONLY



Golder Associates Inc.

Technical Procedure

[illegible]

TP-1.1-4

Revision Level -2-

RECORD OF REVISIONS

<u>Page</u>	<u>Section</u>	<u>Description of Revision</u>
Throughout		Completely rewritten

9 3 1 2 3 4 5 6 7 8 9 10 11 12 13

TP 1.1-4
GROUND PENETRATING
RADAR SURVEYING

Revision Level -2-

September 1990
Page 1 of 5

1. PURPOSE

This technical procedure provides a uniform methodology for executing a ground penetrating radar (GPR) survey to detect subsurface features.

2. APPLICABILITY

This technical procedure is applicable to all GPR surveys conducted using Geophysical Survey Systems Inc. (GSSI) instrumentation.

3. DEFINITIONS

3.1 Ground Penetrating Radar

A ground penetrating radar (GPR) is a geophysical survey instrument consisting of radar frequency (100-500 MHz) antennae mounted on a moveable sled, recording console, and connecting cables.

4. REFERENCES

Ulriksen, C.P., 1982, Application of Impulse Radar to Civil Engineering, Doctoral Thesis, Lund University of Technology.

Geophysical Survey Systems Inc. (GSSI) Operating Manual for SIR system GPR instruments.

5. DISCUSSION

GPR surveys are used to remotely identify shallow subsurface structures such as pipes, drums, or utilities which have significant differences in geo-electric properties from the surrounding soil. Changes in soil type can also be identified under favorable conditions. GPR surveys can be applied in land or over water to map the distribution of soil, ice and permafrost. Exploration depths are very sensitive to soil conditions and can range from less than 3 feet in wet clay to several thousands of feet in polar ice. Like all geophysical survey techniques, there is no guarantee that a GPR survey will detect all subsurface features. Therefore, due care should be exercised in decisions based entirely on geophysical information.

TP 1.1-4
GROUND PENETRATING
RADAR SURVEYING

Revision Level -2-

September 1990
Page 2 of 5

This procedure allows for flexibility in the design and equipment requirements for an individual survey. Specific equipment configurations and survey techniques may vary depending on site conditions. Survey techniques and instrument settings may be changed during the course of a survey as required.

6. RESPONSIBILITY

6.1 Field Engineer

All Field Engineers engaged in conducting GPR surveys are responsible for compliance with this procedure.

7. EQUIPMENT AND MATERIALS

- Radar transmitting and receiver antennae (120,300, or 500 MHz)
- Signal processing console
- Recording instrumentation - one or more of the following:
 - paper recorder
 - analog tape drive
 - digital recorder
 - CRT screen
- Power supply (2 12V auto batteries w/cables)
- Survey cart or vehicle for moving recording equipment along a profile
- 2-3 tape measures (100 to 300 ft)
- Right angle prism (optional)
- Marker tape, flagged at 10 foot intervals
- Stakes, flagging, and fluorescent paint
- Field logbook
- Field Survey Forms (see Exhibit A)
- Geophysical Survey Systems Inc. (GSSI) Operating Manual for SIR system GPR instrument.

8. PROCEDURE

8.1 Establishment of the Survey Grid

Establish surveyed baselines along the primary axes of survey grid and select a survey origin coordinate, designated as a point (0,0). Previously established survey control coordinates should be used wherever possible. Otherwise, select a significant landmark, such as the corner of a building for the survey coordinate (0,0).

Establish line markers along the baselines at 10 to 20 foot intervals, depending on the density of the survey grid. Avoid odd numbered line spacings to simplify the profile between baseline markers.

Select coordinate references by compass direction and distance from (0,0). For example, Line 20E indicates 20 feet east of the origin. A profile run north along line 20E will have coordinate marks at 10N, 20N, and so on.

Make a sketch of the survey grid in the field logbook, and note the coordinate references used for the survey. Figure 8-1 shows an example survey grid.

8.2 Equipment Set-up and Field Calibration

Perform the field calibration procedure outlined in the GSSI manual to optimize the received radar signal for the particular antenna. The field calibration will determine the following instrument settings:

- Full-scale record timing, in nanoseconds,
- Gain settings (early, middle, and late time gains), and
- Filter settings (lo-cut, hi-cut).

Note the instrument settings directly in the field logbooks and on the Field Survey Forms (Exhibit A).

Perform a field check along a test profile and adjust the instrument setting further if necessary. Determine optimum radar antenna towing speed and adjust the paper advance rate accordingly. Make these adjustments over a known target or soil stratigraphy to obtain the best visual representation of that known feature. Document all final adjustments in the field logbook and Field Survey Form.

8.3 Survey Procedure and Documentation

The spacing of the radar profiles may be determined based on prior information regarding the location of buried materials, such as maps, EM data, or other documents. If no prior information is available, the survey shall be conducted at an initial 10 foot spacing.

Each radar profile shall be annotated at the start of the record with the following information:

- Date/Time,
- Site Location,
- Line/profile number and traverse direction,
- Full-scale record timing (ns), and
- Paper advance rate.

Figure 8-2 shows an example radar profile with proper annotation.

Tow the radar antennae along the ground at rate appropriate for the selected chart advance speed.

Fiducial marks shall be remotely placed on the radar record by the antenna operator at 5 to 10 foot intervals. On some antennae, remote markers are not available, and the antennae operator may call out marks to the instrument operator. Significant surface features shall be noted on the radar record. Each radar profile shall also be documented on the Field Survey Form. The Field Survey Form shall contain general field notes relating to the operation of the survey (e.g., noise, surface features, or changes in instrument settings). In addition, sub-surface targets observed by the instrument operator shall be logged on the Field Survey Form by grid location and the depth/reflection time. Additional notation may be added after further examination of the record at the end of the survey.

After examining the records acquired at the initial profile spacing, determine whether additional profiles are required to further define targets of interest. Construct a trackline map of the radar profiles conducted over the site. Significant targets shall be marked on each trackline to produce a map view of subsurface targets. Additional profiles shall be established based on the density of profiles, the location and nature of the observed targets, correlation of targets with prior site information, and quality of the recorded radar data.

Final field documentation shall consist of the grid/trackline/target map, Field Survey Forms, recorded radar profiles, field logbooks, field calibration records, and peripheral recorded data (tape drives or digital recordings). All records shall be forwarded to the Project files.

TP 1.1-4
GROUND PENETRATING
RADAR SURVEYING

Revision Level -2-

September 1990

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8.4 Procedure Alteration Checklist

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on procedure Alteration Checklists (Exhibit B) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Engineers to initiate variations as necessary. If practical, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Engineer, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Procedure Alteration Checklist is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the checklist.

All completed Procedure Alteration Checklists shall be maintained in project records.

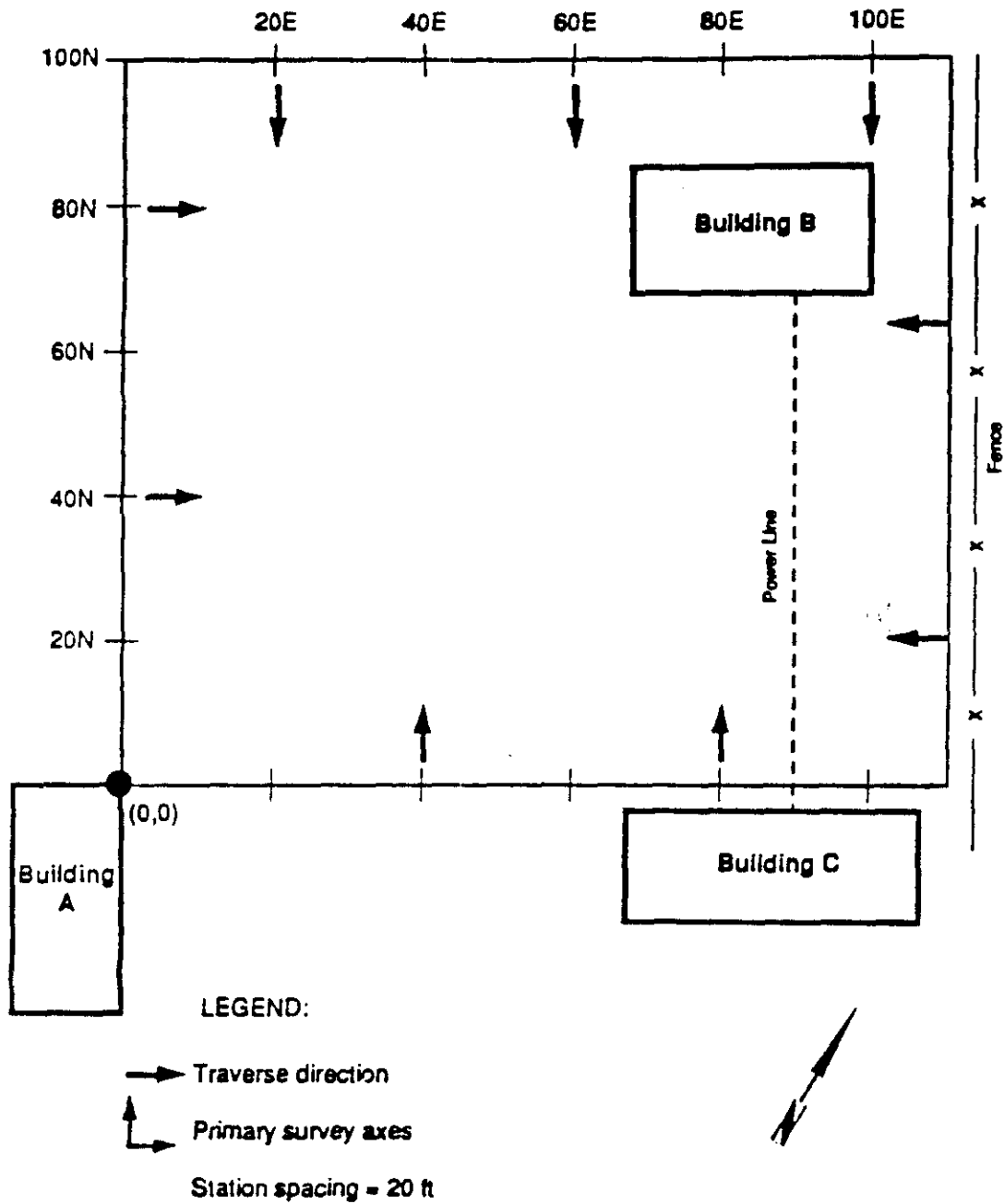


FIGURE 8-1
EXAMPLE SURVEY LAYOUT SKETCH
TECHNICAL PROCEDURES

9 3 1 2 7 5 2 3 3 7 0

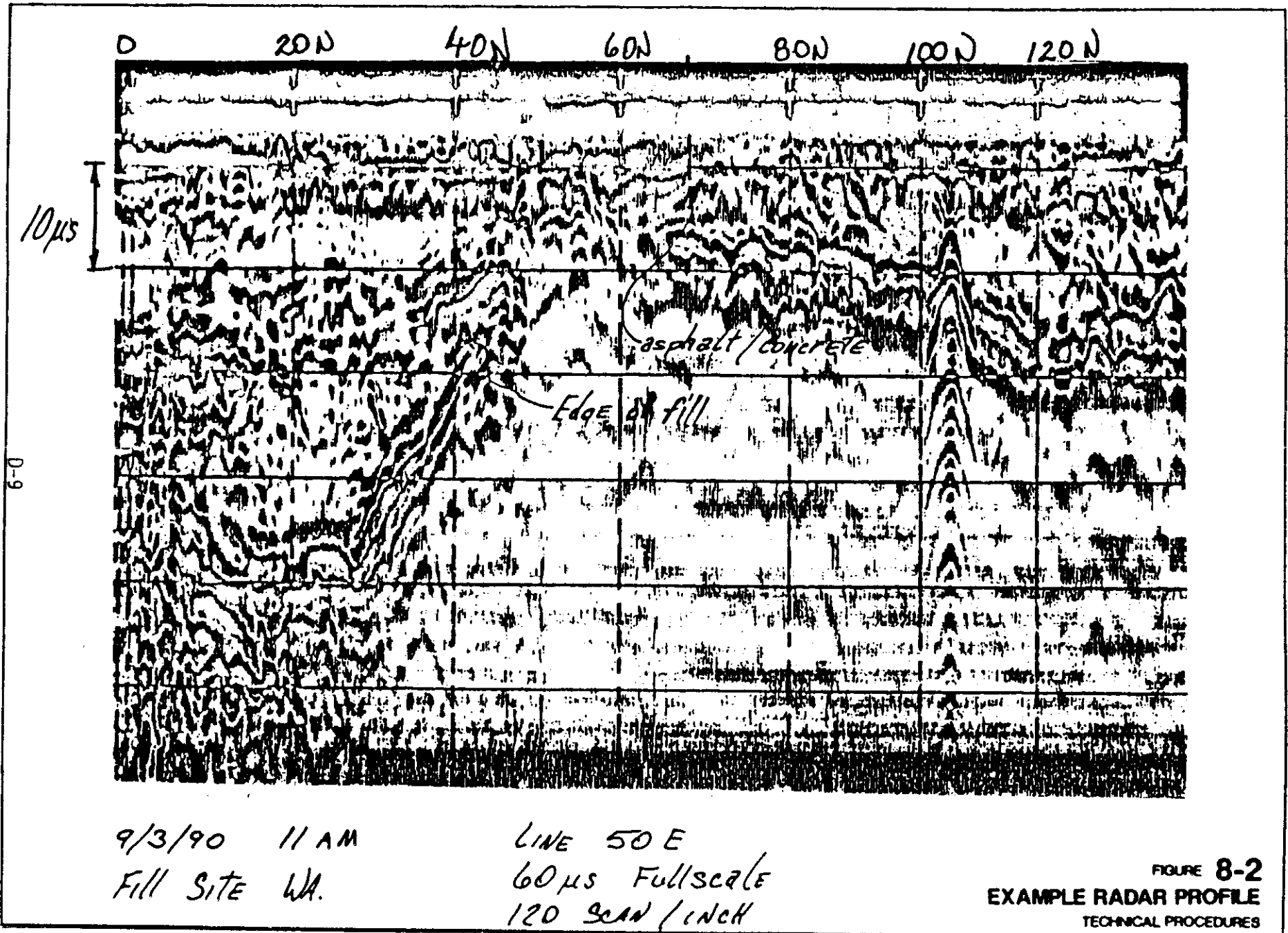


EXHIBIT A

**Golder Associates Inc.**

GPR Field Survey Form

Job No: _____

Location: _____

Date: _____

Weather: _____

Operator: _____

Ground Conditions: _____

Instrument Settings: _____

[illegible]

EXHIBIT B

TP-1.1-4

PROCEDURE ALTERATION CHECKLIST

Job/Task Number: _____

Procedure Reference: _____

Requested Variation: _____

Reason for Variation: _____

Special Equipment, Material or Personnel Required: _____

Alteration Requested By: _____ Date: _____

Title: _____

Reviewed By: _____ Date: _____

Title: GAI Project Manager

Comments: _____

Reviewed By: _____ Date: _____

Title: GAI QA Manager

Comments: _____

Golder Associates

9 3 1 1 7 7 9 1 3 7 2

[illegible]

9312733

TP-1.1-5

RECORD OF REVISIONS

<u>Revision</u>	<u>Page</u>	<u>Section</u>	<u>Description of Change</u>
1	4	8.3	Minor revisions to survey procedure
1	5	8.4	Text modification
1	5	8.4	Additional explanation

93107100074

1. PURPOSE

This technical procedure establishes uniform methodology for executing an electromagnetic survey to detect subsurface features using a GEONICS EM-31 instrument.

2. APPLICABILITY

This technical procedure is applicable to all electromagnetic surveys conducted using a GEONICS EM-31 instrument.

3. DEFINITIONS

3.1 Primary Field

The primary field refers to the electromagnetic field generated at the transmitter.

3.2 Secondary Field

The secondary field is the electromagnetic field induced by the primary field and is a function of the subsurface geo-electric properties. The receiver measures both the primary and secondary magnetic field, but the instrument reading automatically subtracts the primary field.

3.3 In-phase Component

The in-phase component is the part of the secondary field that is in-phase with the primary field. Very conductive materials cause the secondary field to be more in-phase than non-conductive materials. Therefore, the in-phase data is used to locate highly conductive objects, such as metal. The in-phase component is measured with the instrument in COMP mode.

3.4 Quadrature Component

The quadrature component is the part of the secondary field that is out-of-phase, or at an angle to, the primary component. This is generally the strongest component of the secondary field when measuring natural soils, and is the standard operating mode of the EM-31 instrument. The quadrature component is measured with the instrument in OPER mode.

3.5 Apparent Ground Conductivity

Apparent ground conductivity is the total conductivity measured by the instrument, based on the strength of the secondary magnetic field. It includes the individual conductivities of any differing subsurface layers, and is therefore not an absolute measure of ground conductivity. All interpretations of EM-31 data are based on apparent ground conductivities.

4. REFERENCES

GEONICS Ltd., 1984, Operating Manual for EM-31D Non-Contacting Terrain Conductivity Meter

GEONICS Ltd., 1984, Technical Note TN-5, Electrical Conductivity of Soils and Rocks.

GEONICS Ltd., 1984, Technical Note TN-6, Electromagnetic Terrain Conductivity Measurements at Low Induction Numbers.

Slaine, D.D, and Greenhouse, J.P., 1982, "Case Studies of Geophysical Contaminant Mapping at Several Waste Disposal Sites;" Proc. 2nd National Symp. on Aquifer Restoration and Groundwater Monitoring, Columbus OH, pp. 299-315.

5. DISCUSSION

Electromagnetic surveys can be used to remotely identify shallow subsurface structures which have significant differences in geo-electric properties from the surrounding soil. These structures include pipes, drums, utilities, or changes in soil type, saturation, or composition. Electromagnetic surveys can also be used to map the general distribution of soils with differing geo-electric properties. The EM-31 can be used for exploration depths of up to 18 feet, depending on soil conditions. No geophysical technique can detect all subsurface features and care should be exercised in decisions based entirely on geophysical information.

The technique for EM-31 surveys are relatively straightforward, compared to many other geophysical surveys. However, specific equipment configurations and survey techniques may vary depending on site conditions. The EM-31 is designed for operation by one person, and a properly planned survey can normally cover about 3 acres per day.

6. RESPONSIBILITY

6.1 Field Engineer

All Field Engineers engaged in conducting EM-31 surveys are responsible for compliance with this procedure.

7. EQUIPMENT AND MATERIALS

- EM-31 unit consisting of transmitter and receiver coil mounted on a 6m boom;
- PolyCorder automatic data logging unit (optional);
- 2-3 tape measures (100 to 300 ft);
- Marker tape/rope, flagged at 20 foot intervals;
- Right-angle prism (optional);
- Stakes, flagging, and fluorescent paint;
- Field logbook;
- Field Survey Forms; (see Exhibit A); and
- GEONICS EM-31 operating manual.

8. PROCEDURE

8.1 Establish the Survey Grid

Establish surveyed baselines along the primary axes of the survey grid and select a survey origin coordinate (0,0). The primary axes should be referenced to compass bearings. Previously established survey control coordinates should be used wherever possible. Otherwise, select a significant landmark, such as the corner of a building for the survey origin coordinate (0,0).

Establish line markers along the baselines at 10 to 20 foot intervals, depending on the density of the survey grid. Avoid odd numbered line spacings to simplify the profile between baseline markers.

Select coordinate references by compass direction and distance from (0,0). For example, Line 20E indicates 20 feet east of the origin. A profile run north along line 20E will have coordinate marks at 10N, 20N, and so on.

Make a sketch of the survey grid in the field logbook, and note the coordinate references used for the survey. Figure 8-1 shows an example survey layout sketch.

8.2 Equipment Set-up and Functional Tests

Perform equipment set up procedures and functional tests of the equipment, as outlined in the EM-31 operating manual.

Make a traverse with the instrument over an area outside of the proposed survey area, preferably at a geologically characterized calibration site. Record ground conductivities in both vertical and horizontal orientations and in both OPER and COMP modes. If possible, make another test profile over a known target or soil type, and record all readings in the field logbook.

8.3 Survey Procedure and Documentation

Starting at (0,0), traverse the grid in serpentine fashion along one principal axis of the grid. It is not necessary to traverse the grid in the same direction for each line as long as the each station number is recorded on the Field Survey. For each line, record the direction of the traverse. Record the following instrument readings for each station on the Field Survey Form or field logbook:

- Station number or location;
- Instrument Mode (OPER and COMP);
- Coil orientation (vertical and horizontal);
- Instrument orientation (parallel and perpendicular to line direction). Measure both parallel and perpendicular instrument orientations at each station;
- Apparent ground conductivity for each mode, coil, and orientation; and
- Other appropriate comments (e.g., proximity to surface features).

All field logbooks, functional test data, and Field Survey Forms shall be forwarded to the project files.

8.4 Data Reduction

All survey data will be entered into a computerized database or spreadsheet, such as a LOTUS table, for plotting purposes, and for subsequent data analysis and contouring. Digitally acquired data using the PolyCorder can be downloaded to files using the data processing program DAT31Q. Consult the Geonics DAT31Q manual for specific details on data downloading. The data should be formatted by station coordinate. A separate raw data file containing station location and apparent conductivity should be generated for each of the following:

- In phase, horizontal coil, parallel to line direction (IHP)
- In phase, vertical coil, parallel to line direction (IVP)
- Quadrature, horizontal coil, parallel to line direction (QHP)
- Quadrature, vertical coil, parallel to line direction (QVP)

A similar set of four files should be generated for measurements taken with the instrument perpendicular (Q) to the line direction. This would correspond to IHQ, IVQ, QHQ, and QVQ files. File specifiers (IHP and so on) are optional.

8.5 Procedure Alteration Checklist

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on procedure Alteration Checklists (Exhibit B) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Engineers to initiate variations as necessary. If practical, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Engineer, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Procedure Alteration Checklist is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the checklist.

All completed Procedure Alteration Checklists shall be maintained in project records.

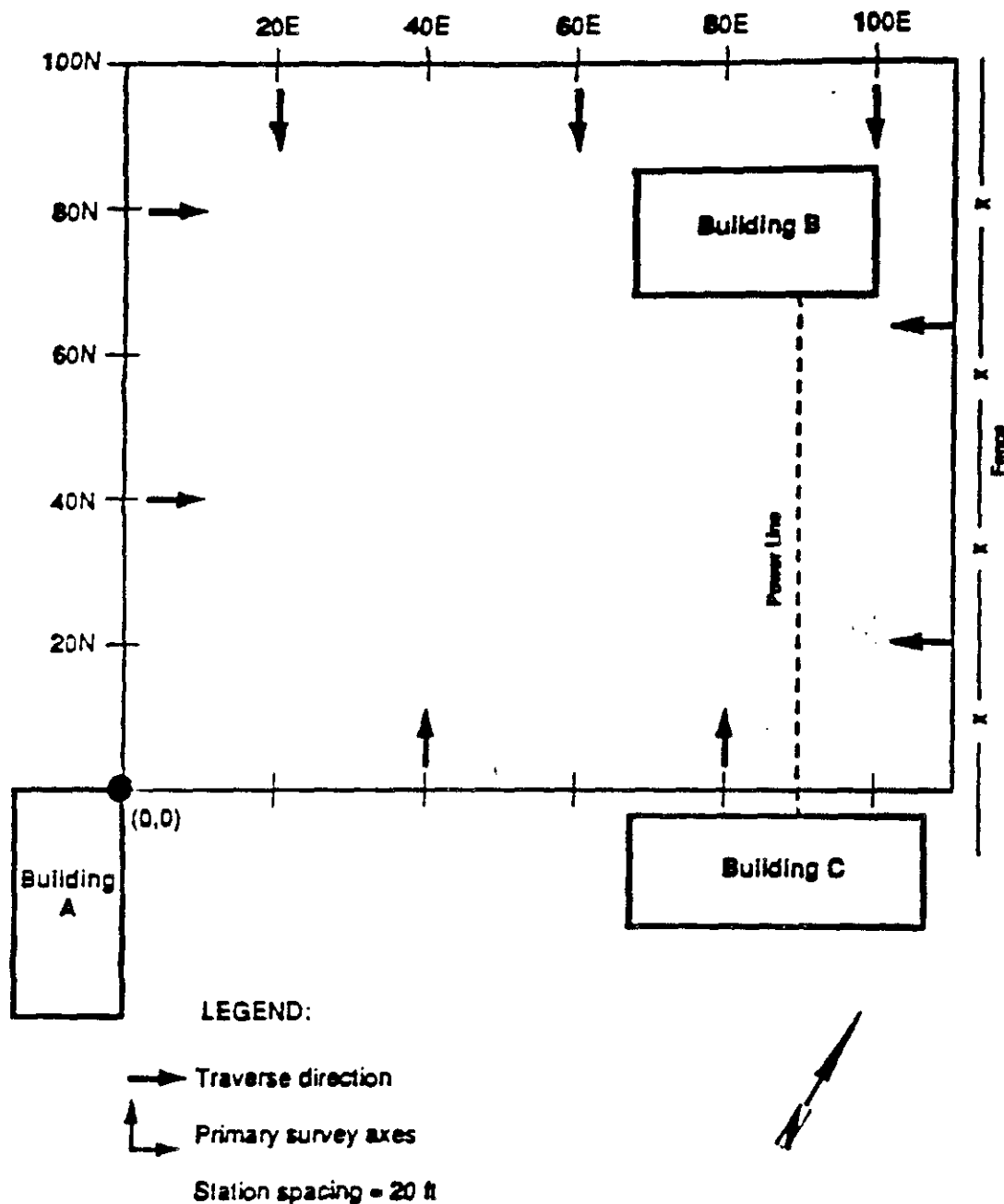


FIGURE 8-1
EXAMPLE SURVEY LAYOUT SKETCH
TECHNICAL PROCEDURES



Golder Associates Inc.

EM-31 Field Survey Form

Job No: _____ **Location:** _____

Date: _____ Line Number: _____

Operator:	Weather:

Ground Conditions:

Instrument Settings:

[illegible]

TP-1.1-5

EXHIBIT B

PROCEDURE ALTERATION CHECKLIST

Job/Task Number: _____

Procedure Reference: _____

Requested Variation: _____

Reason for Variation: _____

Special Equipment, Material or Personnel Required: _____

Alteration Requested By: _____ Date: _____

Title: _____

Reviewed By: _____ Date: _____

Title: GAI Project Manager

Comments: _____

Reviewed By: _____ Date: _____

Title: GAI QA Manager

Comments: _____

Golder Associates

9312700002



Technical Procedure

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931272733

1. PURPOSE

This technical procedure establishes uniform methodology for executing a magnetometer survey to detect subsurface features using a EG&G 856 proton precession magnetometer.

2. APPLICABILITY

This technical procedure is applicable to all electromagnetic surveys conducted using a EG&G 856 proton precession magnetometer.

3. DEFINITIONS

3.1 Total Magnetic Field

The total magnetic field is the magnitude of the earth's magnetic field vector, independent of its direction.

3.2 Anomaly

The anomaly is the difference between the undisturbed total magnetic field of the earth and the disturbed total magnetic field of the earth caused by the presence of ferromagnetic materials in the subsurface.

4. REFERENCES

Breiner, S., 1973, Applications Manual for Portable Magnetometers.

EG&G Geometrics MAGPAC Version 4.1 Users Manual.

5. DISCUSSION

Magnetometer surveys can be used to remotely identify metallic objects in the subsurface. The presence of ferromagnetic materials in the subsurface disturbs the total magnetic field of the earth and this disturbance can be measured in using a portable magnetometer. These disturbances are represented as anomalies, which shows the difference between the natural undisturbed total magnetic field (measured at a base station) and the disturbed total field measured during the survey. In addition to total magnetic field, a magnetometer survey can measure the vertical gradient of the total field. Gradient, or gradiometer data is useful in interpreting magnetometer surveys because it enhances the response of shallow sources. The precession magnetometer measures the magnetic field vector and does not resolve the components of the field. Magnetometer surveys require a base station from which regular measurements of the undisturbed total magnetic field are measured. These

measurements are then used to produce anomaly maps and profiles from the survey data.

6. RESPONSIBILITY

6.1 Field Engineer

All Field Engineers engaged in conducting magnetometer surveys are responsible for compliance with this procedure.

7. EQUIPMENT AND MATERIALS

- Magnetometer unit consisting of recording unit, sensors mounted on a staff, and backpack assembly.
- 2-3 tape measures (100 to 300 ft);
- Marker tape/rope, flagged at 20 foot intervals;
- Right-angle prism (optional);
- Stakes, flagging, and fluorescent paint;
- Field logbook;
- Field Survey Forms; (see Exhibit A); and
- EG&G 856 magnetometer operating manual.
- MAGPAC Version 4.1 Users Manual.

8. PROCEDURE

8.1 Establish the Survey Grid

Establish surveyed baselines along the primary axes of the survey grid and select a survey origin coordinate (0,0). The primary axes should be referenced to compass bearings. Previously established survey control coordinates should be used wherever possible. Otherwise, select a significant landmark, such as the corner of a building for the survey origin coordinate (0,0).

Establish line markers along the baselines at 10 to 20 foot intervals, depending on the density of the survey grid. Avoid odd numbered line spacings to simplify the profile between baseline markers.

TP 1.1-7

MAGNETOMETER SURVEYING **Revision Level - 0 -**

April 1991

Page 3 of 4

Select coordinate references by compass direction and distance from (0,0). For example, Line 20E indicates 20 feet east of the origin. A profile run north along line 20E will have coordinate marks at 10N, 20N, and so on.

Make a sketch of the survey grid in the field logbook, and note the coordinate references used for the survey. Figure 8-1 shows an example survey layout sketch.

8.2 Equipment Set-up and Functional Tests

Perform equipment set up procedures and functional tests of the equipment, as outlined in the EG&G 856 operating manual.

Make a traverse with the instrument over an area outside of the proposed survey area, preferably at a geologically characterized calibration site, and record total magnetic field. If possible, make another test profile over a known target or soil type, and record all readings in the field logbook.

8.3 Survey Procedure and Documentation

After functional checks of the instrument(s) are performed a base station should be established. The base station should be located away from away potential magnetic or electromagnetic noise sources (fences, power lines, buried pipelines). Successive readings at the base station should be within ± 1 gamma or 0.25 gammas, depending on the sensitivity of the instrument. Once the base station has been established, it should be reoccupied once every hour to record short term fluctuations in the magnetic field. The base station may be set up with a separate instrument if the survey area is large or difficult to traverse. The orientation of the sensor should be consistent with the orientation used on the survey grid. Ideally, the sensor should be oriented at right angles to the earth's field direction. An arrow at the top of the sensor indicates the sensor orientation. The operator should insure that he/she is free of sources of magnetic noise such as a compass, pocket knife or tape recorder, prior to initiating the survey.

Traverse the grid along successive lines, always starting at one end of the grid if possible. At the beginning of each line, record the line number, time, and sensor orientation. For each station along the line record the station number, magnetic field value(s), and appropriate comments (e.g. proximity to surface features). If gradiometer measurements are being taken, two magnetic field values will be recorded for each station.

All field logbooks, functional test data, and Field Survey Forms shall be forwarded to the project files.

8.4 Data Reduction

Data recorded in the solid state memory of the instrument can be downloaded to a computer disk using the computer program MAGPAC. Consult the MAGPAC manual for specific details on data down loading. For subsequent data analysis and interpretation, all

data should be formatted by station coordinate. Produce separate raw data files for the total magnetic field and for the vertical total field gradient. The base station record should also be provided in a separate file. Residual, or anomaly files produced using the survey and base station data should also be provided in a separate file.

8.5 Procedure Alteration Checklist

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on procedure Alteration Checklists (Exhibit B) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Engineers to initiate variations as necessary. If practical, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Engineer, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Procedure Alteration Checklist is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the checklist.

All completed Procedure Alteration Checklists shall be maintained in project records.

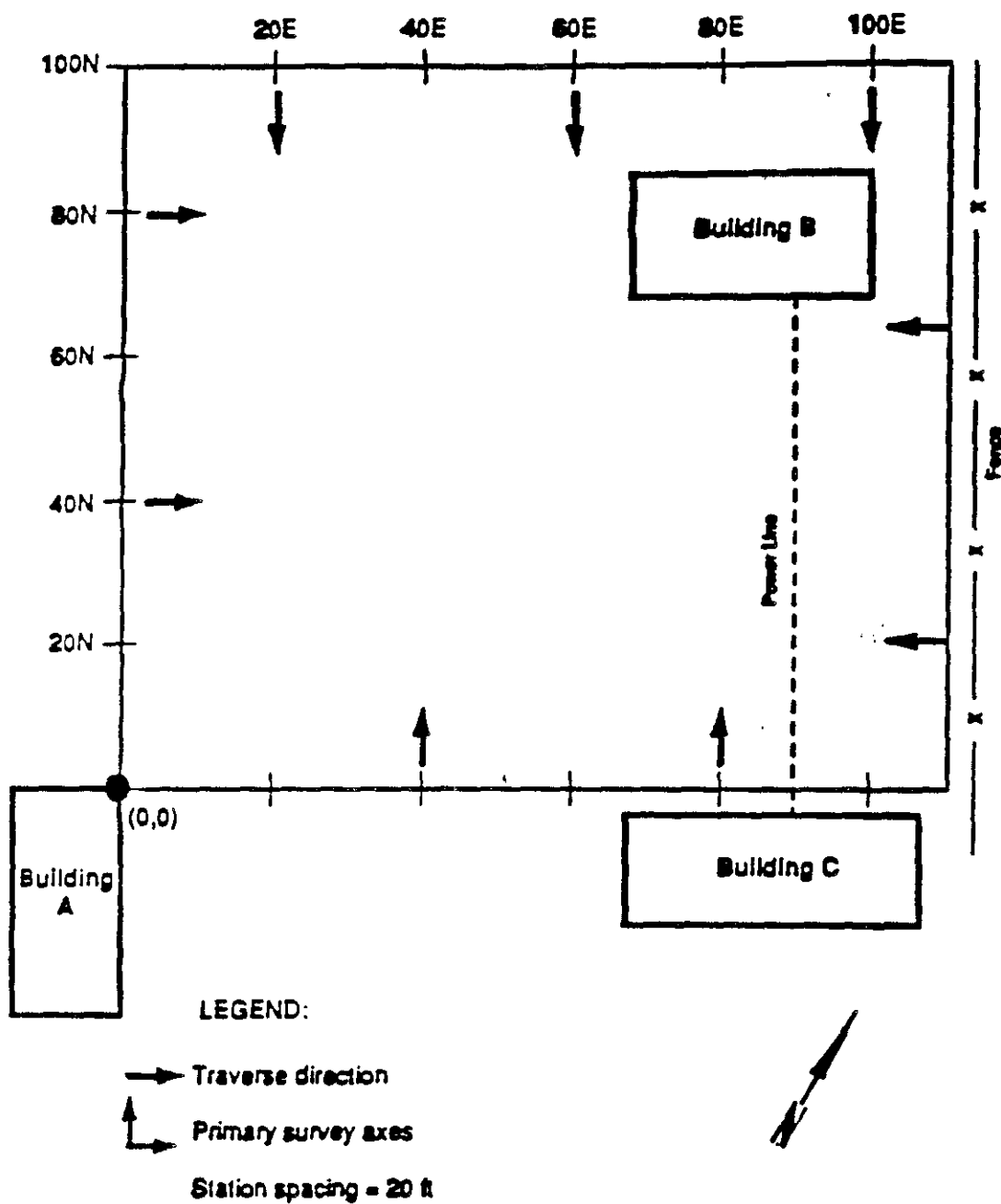


FIGURE 8-1
EXAMPLE SURVEY LAYOUT SKETCH
TECHNICAL PROCEDURES

**Golder Associates Inc.**

Magnetometer Field Survey Form

Job No: _____

Location: _____

Date: _____

Line Number: _____

Operator: _____

Weather: _____

Ground Conditions: _____

Instrument Settings: _____

[illegible]

TP-1.1-7

EXHIBIT B

PROCEDURE ALTERATION CHECKLIST

Job/Task Number: _____

Procedure Reference: _____

Requested Variation: _____

Reason for Variation: _____

Special Equipment, Material or Personnel Required: _____

Alteration Requested By: _____ Date: _____

Title: _____

Reviewed By: _____ Date: _____

Title: GAJ Project Manager

Comments: _____

Reviewed By: _____ Date: _____

Title: GAJ QA Manager

Comments: _____

Golder Associates

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